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EVALUATION OF HEALTH RISKS ASSOCIATED WITH WASTEWATER TREATMENT AND SLUDGE COMPOSTING

by

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16. ABSTRACT

This investigation included (1) a prospective study of wastewater sludge compost workers, (2) serologic analyses of wastewater-exposed workers, (3) a mortality study of former wastewater employees, and (4) chemical analyses of specimens from a population whose drinking water was contaminated with pesticide waste dump leachate. The compost worker study involved workers and controls in 3 cities. An excess of skin, nose, and ear conditions was detected and tests were suggestive of low-grade inflammatory response. Aspergillus fumigatus were frequently detected in throat and nasal swabs of compost workers and were rarely detected in workers with little or no compost exposure. Analysis of sera from wastewater workers reporting G.I. illness indicated that among inexperienced workers Norwalk agent was associated with 13% of illness. Anti-HAV was not different among worker and control groups. An analysis of 815 death certificates from former wastewater workers revealed that for relatively rare causes of death, leukemia and cancer of the esophagus, the proportions of workers with these causes of death was about twice as many as expected. Less than 1/2 as many deaths as expected were observed for pneumonia. Concentrations of thioethers in urine were not significantly higher in workers at a plant receiving wastes from a pesticide manufacturer, than in those from a control plant and were also not significantly higher in individuals previously exposed to chemically-contaminated drinking water than in controls.

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FOREWORD

The many benefits of our modern, developing, industrial society are accompanied by certain hazards. Careful assessment of the relative risk of existing and new man-made environmental hazards is necessary for the establishment of sound regulatory policy. These regulations serve to enhance the quality of our environment in order to promote the public health and welfare and the productive capacity of our Nation's population.

The complexities of environmental problems originate in the deep interdependent relationships between the various physical and biological segments of man's natural and social world. Solutions to these environmental problems require an integrated program of research and development using input from a number of disciplines. The Health Effects Research Laboratory, Research Triangle Park, NC and Cincinnati, OH conducts a coordinated environmental health research program in toxicology, epidemiology and clinical studies using human volunteer subjects. Wide ranges of pollutants known or suspected to cause health problems are studied. The research focuses on air pollutants, water pollutants, toxic substances, hazardous wastes, pesticides and non-ionizing radiation. The laboratory participates in the development and revision of air and water quality criteria and health assessment documents on pollutants for which regulatory actions are being considered. Direct support to the regulatory function of the Agency is provided in the form of expert testimony and preparation of affidavits as well as expert advice to the Administrator to assure the adequacy of environmental regulatory decisions involving the protection of the health and welfare of all U.S. inhabitants.

This report provides results on research into the potential health effects related to wastewater treatment plant sludge composting and municipal wastewater treatment in occupationally-exposed populations and related to toxic waste dump leachate in a small community. With a better understanding of the health effects, measures can be developed to reduce exposure to potentially harmful materials.

F. Gordon Hueter, Ph.D.
Director
Health Effects Research Laboratory

ABSTRACT

The risks to human health from exposures to biological and chemical agents in waste materials are a primary motivating factor for the improvement in practices for storing, transporting, treating and ultimately disposing of these wastes. Four areas of research of potential health effects related to waste exposures from wastewater treatment plant sludge composting, municipal wastewater treatment, and toxic waste dump leachate, were undertaken under this Cooperative Agreement. The specific areas were: (1) a prospective health study of workers engaged in the composting of wastewater treatment plant sludge, (2) serologic analyses of inexperienced and experienced wastewater-exposed workers, (3) a mortality study of former employees of a large wastewater treatment system, and (4) selected chemical analyses of biological specimens from a population whose drinking water had been contaminated with leachate from a pesticide waste dump. Each of these studies had its origins in previous research undertakings, the results of which have been reported elsewhere.

The compost worker study involved workers at compost sites in Camden, NJ, Philadelphia, PA, Beltsville, MD and Washington, D.C. and control groups. Among the findings of the study were an excess of abnormal skin, nose and ear conditions as detected by physical examinations of the workers. In addition, several of the laboratory tests were suggestive of low-grade inflammatory response. Viable units of the fungus Aspergillus fumigatus were frequently detected in cultures of throat and nasal swabs of compost workers and were rarely detected in workers with little or no compost exposure. The effects observed in the compost worker study may be due to the nature of the compost process itself and therefore may not be related specifically to the use of wastewater sludge in the composting operations. However, they do justify a continuation of health studies of workers engaged in the composting of waste materials. The fact that sludge composting has been practiced for a relatively short period of time adds to the need for additional study.

Using a serum bank established in an earlier study of wastewater workers and controls in Cincinnati, OH, Chicago, IL and Memphis, TN the present study evaluated possible viral factors that may be included in the previously detected excess in gastrointestinal illness observed among workers during their first two years of wastewater employment. Testing for antibody to Hepatitis A (anti-HAV) virus was among the other tests performed. Analysis of paired sera from workers who reported gastrointestinal illness indicated that among inexperienced workers Norwalk agent was associated temporally with 13% of these illnesses. Inexperienced wastewater-exposed workers had higher levels of antibody to Norwalk agent than did experienced and control workers ($p = 0.03$). The presence of anti-HAV was not different among the inexperienced wastewater

workers, experienced wastewater workers, and controls and was not associated with length of wastewater exposure for the exposed wastewater workers. However, anti-HAV was found to be associated with race ($p \leq 0.0001$) and age ($p < 0.001$).

An analysis of 815 death certificates from former workers at the Metropolitan Sanitary District of Greater Chicago revealed that for a relatively rare cause of death, leukemia (1 in 134), the proportion of workers with this cause of death was about twice as many as expected (11 observed, 6 expected: $p = .04$). For another relatively rare cause of death, cancer of the esophagus (1 in 215) there was also about twice as many observed as expected deaths which was almost significant using U.S. Vital Statistics ($p = 0.08$) but not using Illinois Vital Statistics ($p = 0.13$). A more common cause of death, pneumonia (1 in 41), less than one-half as many deaths as expected were observed ($p = 0.02$). Recommendations for further study are made.

A previous study of a population whose drinking water had been heavily contaminated with leachate from a pesticide waste dump had revealed higher levels of serveral liver function tests and enlarged livers among the exposed population. In the present study specimens available from the earlier study were examined to determine if specific contaminants could be detected in the serum or if an overall indication of chemical exposure, urinary thioether concentrations, was elevated. Analysis for volatile organic chemicals in serum from individuals whose drinking water had previously been contaminated did not reveal higher levels when compared with results from specimens from non-exposed individuals. Concentrations of thioethers in urine specimens were not found to be significantly higher in specimens from workers at a wastewater treatment plant receiving wastes from a pesticide manufacturer, than in those from a control plant and were also not significantly higher in individuals previously exposed to chemically-contaminated drinking water than in controls.

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In health studies of human populations the cooperation of a great many individuals and organizations is essential. Frequently even individuals with whom the investigators have no direct contact, such as family and friends of study volunteers and staff of the cooperating agencies, are among those contributing to a study's success. We are indeed grateful to all of those whose efforts have assisted our work. Since many individuals and organizations involved in earlier aspects of the four studies reported here have been previously acknowledged in U.S. EPA reports we will not attempt to be exhaustive here.

For the compost worker study we want to again thank workers and their organizations in the several locations involved: Camden, NJ, Philadelphia, PA, Beltsville, MD and Washington, D.C. Mr. Joe Holland and Ms. Janet Fulton, M.S.N. were the key individuals on our team on the compost worker study. The many trips and many long hours that they and their colleagues worked so competently will never be forgotten. For the continual work on sera from our former wastewater worker study we are appreciative of the analysis performed in the laboratories of Drs. John Phair and Raymond Zeiss of Northwestern University and Dr. Neil Blacklow of the University of Massachusetts. The continued cooperation for our mortality study by the Metropolitan Sanitary District of Greater Chicago (Dr. Cecil Lue-Hing, in particular) and the Sanitary District Employee's and Trustees' Annuity and Benefit Fund (Mr. Thomas Gregos, in particular) is also sincerely appreciated.

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SECTION 1

INTRODUCTION

The risks to human health from exposures to biological and chemical agents in waste materials are a primary motivating factor for the improvement in practices for storing, transporting, treating and ultimately disposing of these wastes. Four areas of research of potential health effects related to waste exposures from wastewater treatment plant sludge composting, municipal wastewater treatment, and toxic waste dump leachate, were undertaken under this Cooperative Agreement. The specific areas were: (1) a prospective health study of workers engaged in the composting of wastewater treatment plant sludge, (2) serologic analyses of inexperienced and experienced wastewater-exposed workers, (3) a mortality study of former employees of a large wastewater treatment system, and (4) selected chemical analyses of biological specimens from a population whose drinking water had been contaminated with leachate from a pesticide waste dump. Each of these studies had its origins in previous research undertakings, the results of which have been reported elsewhere (1-8). The compost workers study (2,5,7) and the mortality studies (4) were a continuation and an expansion, respectively, of earlier studies. The other two projects made use of serum and urine available from previously-completed studies (1,3,6, 8).

The ultimate disposition of the residuals resulting from the treatment of municipal wastewaters, i.e. sludges, has been a major problem facing many municipalities. Legislation which prohibited ocean dumping of sludge after 1981 has forced many municipalities to develop alternative disposal methods. One option which has been considered is the application of wastewater and sludge to the land for crop irrigation or as an organic soil amendment. The composting of sewage sludge has been shown to yield a product which appears to be biologically safe and well suited for ultimate land disposal. The composting of wastewater treatment plant sludge has increased considerably in the past several years in the U.S.A. and elsewhere. As recently as ten years ago sludge composting in the U.S.A. was practiced mainly by Los Angeles County, using the windrow method. The development of the aerated pile method by the U.S. Department of Agriculture at Beltsville, MD, prohibitions against ocean dumping, and the increased cost of alternative sludge treatment methods have led to a rapid expansion in systems for composting sludge prior to its land application.

Successful year round outdoor composting sites are operating in many areas of the Northeast and Midwest. Currently, Philadelphia, PA, Camden, NJ, Washington, D.C., Columbus, OH, Windsor, Ontario, Bangor and Portland, ME, as well as other smaller cities, have initiated composting of municipal sludge by the aerated pile method. Although pathogenic bacteria and viruses

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are effectively reduced in numbers by the high temperatures achieved in composting, conditions are ideal for the growth of thermophilic microorganisms, such as the fungus *Aspergillus fumigatus*. Therefore, workers directly associated with the composting process will be exposed to high concentrations of microorganisms; not only those microorganisms present in the raw sludge, but also those which proliferate during the composting process, such as *Aspergillus fumigatus*. The dust at composting sites has also been shown to contain significant quantities of lipopolysaccharide (LPS) derived from viable and non-viable gram-negative microorganisms which are present in sludge. Workers at composting sites are exposed to potential human pathogens, bacterial endotoxins, and other microbial toxins via inhalation of dust generated by manipulation of the compost piles and by inadvertent ingestion of compost or sludge, through dirtying of the hands or face with compost or sludge and subsequent transport to the mouth. The compost workers study included in the Cooperative Agreement has focussed on an evaluation of the health effects of chronic, long-term exposure of workers at composting facilities to the combination of microbial pathogens, microbial toxins, and LPS present in the work environment at composting sites.

The potential health effects of exposure to municipal wastewater treatment processes are not only important to the workers at these plants and ultimately to designers of these plants and others involved in their construction, financing and regulations, but also to communities which are neighbors to existing and future plants. An infectious disease study of municipal wastewater treatment plants in Cincinnati, OH, Chicago, IL and Memphis, TN, (1) concluded that although no evidence was found to support the existence of any significant health effects of occupational exposure to viruses in wastewater, an excess of reports of gastrointestinal illnesses was detected among the inexperienced wastewater-exposed workers. In addition, several recommendations for additional studies were made to aid in the interpretation of the results (Appendix A). These recommendations have been carried out under this Cooperative Agreement.

Another approach to determine health effects of occupational exposure to wastewater treatment operations is a study of the causes of death of former employees in wastewater treatment systems. An interim report on such a study was presented by us at a 1979 EPA symposium (4). The interim report of former employees of the Metropolitan Sanitary District of Greater Chicago did not indicate any excesses of any of the major causes of death. This mortality study was expanded under the present Cooperative Agreement to include twice as many decedents and to include more detail on causes of death and to examine the relationship between cause of death and various aspects of employment history.

Human health risks from improper disposal of toxic wastes has become an increasingly important issue in recent years. A study of the health effects on a rural community in western Tennessee from leachate from a pesticide waste dump was conducted under a previous U.S. EPA grant (2). In the Hardeman County study we had detected abnormalities in certain liver function tests and an excess of people with enlarged livers in the exposed population when compared to controls (6). Exposure had been well-documented by means of water analyses by various public agencies and by limited air sampling that we had conducted. However, only limited biological monitoring had been included in the previous study and the emphasis of it was on compounds we were investigating elsewhere and not on the more abundant compounds in the contaminated well water. Under the present Cooperative Agreement additional biological monitoring was undertaken on the Hardeman County population and on a wastewater worker population exposed to the same wastes. Some of this research was performed under a U.S. EPA Cooperative Agreement at the University of Miami, Florida.

SECTION 2

CONCLUSIONS

(1) Physical examinations of the workers participating in this study revealed an increased incidence of the following abnormal findings in compost and intermediate-exposed workers: acute and/or chronic inflammation or infection of the skin, evidence of acute and/or chronic inflammation of the nasal mucosa and eyes, and evidence of acute and chronic infections of the ear. The high prevalence of these findings in compost and intermediate-exposed workers and not in the controls suggests that they may be related to compost exposure.

(2) The presence of an occupational pulmonary disease was detected on the chest X-ray in one worker with four years exposure to composting. Due to the small numbers of workers with >3 years work exposure in the study, this may be very significant.

(3) Compost workers had no evidence of abnormalities of liver or renal function during the study period.

(4) Hemolytic complement (CH_{50}) titers and white blood cell counts were elevated in compost workers as compared to controls; the elevations were not observed during all sampling periods and may have been related to seasonal variations in exposure conditions at the compost sites. Concentrations of C3 and C-reactive protein were similar among all exposure groups.

(5) There was no correlation of serum concentrations of the immunoglobulins G, M, A, and E by worker exposure group.

(6) Compost workers appear to have higher levels of IgG antibody against compost-derived lipopolysaccharide.

(7) Compost exposure does not seem to have a consistent effect on levels of IgG antibody against _A. fumigatus_.

(8) Extremely high numbers of _A. fumigatus_ and "other thermophilic fungi" were detected in the environment at the compost sites studied; both total and respirable numbers were significantly above expected background levels. Highest concentration of fungi were detected downwind from active compost sites.

(9) Cultures of the throat and anterior nares of workers at compost sites were frequently positive for _Aspergillus fumigatus_; similar cultures obtained from workers in the intermediate-exposed and control groups (exposure groups II and III) were almost always negative for _A. fumigatus_. These results

demonstrate that exposure of workers to high concentrations of fungal spores in the work environment results in viable colony forming units of the fungi being routinely present in the upper respiratory tract.

(10) All workers screened lacked precipitating antibodies to the following antigens: H and M antigens of *Histoplasma capsulatum*; and a pool of antigens prepared from *A. fumigatus*, *A. flavus*, *A. carneus*, and *A. niger*. These results suggest that infection caused by these fungi were uncommon among the workers studied, despite exposure of workers at compost facilities to extremely high numbers of fungal spores.

(11) Seroconversions to *Legionella pneumophila* were more common in study participants in the Camden-Philadelphia area than in the Washington, D.C. metropolitan area. However, there was no evidence of increased risk of infection in compost-exposed workers caused by this organism suggesting that exposure to *Legionella* species is not a risk of sludge compost employment.

(12) There appears to be a pattern of increased numbers of symptoms of skin irritation and burning eyes among compost-exposed workers compared to those non-exposed during the fall and winter seasons.

(13) Wastewater-exposed workers in the study do not appear to be at increased risk to infection with hepatitis A. Antibody to hepatitis A was found to be more prevalent in black workers than in white workers and was positively associated with age.

(14) In Cincinnati, an apparent infection with Echovirus 3, which had previously been suspected on the basis of isolation of the virus from throat and rectal swabs, was serologically detected in inexperienced sewage-exposed workers. An infection with Echovirus 6, detected by a previous study through rising titer levels from January-October 1977, was apparently preceded by an infection in 1976 as evidenced by higher antibody prevalence but not by statistically higher titer level rises.

(15) About 13% of the gastroenteritis reported by inexperienced sewage-exposed workers appears to be associated with Norwalk agent. Infection with Norwalk agent appears to be a risk of the first two years of exposure to wastewater and it may also be associated with level of biological aerosol exposure.

(16) Antibody to the alga prototheca does not appear to be consistently higher among wastewater-exposed workers than control groups.

(17) An analysis of 815 death certificates from workers in a wastewater treatment system revealed that for a relatively rare cause of death, leukemia (1 in 134), the proportion of workers with this cause of death was about twice as many as expected (11 observed, 6 expected: $p = .04$). For another relatively rare cause of death, cancer of the esophagus (1 in 215) there was also about twice as many observed as expected deaths which was almost significant using U.S. Vital Statistics ($p = 0.08$) but not using Illinois Vital Statistics ($p = 0.13$). For

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a more common cause of death, pneumonia (1 in 41), less than one-half as many deaths as expected were observed (p = 0.02).

(18) Analysis for volatile organic chemicals in serum from individuals whose drinking water had previously been contaminated by a pesticide waste dump did not reveal higher levels when compared with results from specimens from non-exposed individuals.

(19) Concentrations of thioethers in urine specimens were not found to be significantly higher in specimens from workers at a wastewater treatment plant receiving wastes from a pesticide manufacturer, than in those from a control plant and were also not significantly higher in individuals previously exposed to chemically-contaminated drinking water than in controls.

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SECTION 3

RECOMMENDATIONS

(1) Physical examinations should be conducted on as many of the original compost study participants as possible and on additional compost workers to determine if the abnormal findings evident in this study regarding skin, nose, ears and eyes can be confirmed. These examinations should include: cultures of anterior nares and oropharyngeal swabs, complete blood count with differential, serum gamma glutamic transaminase, ELISA-determined IgG antibody against compost-derived LPS, CH_{50} and IgE.

(2) Investigations should be conducted of the long term effects of exposure to composting on the pulmonary system: included in the testing should be: pulmonary function testing, chest X-ray and physical exam.

(3) It is important to determine whether individuals with chronic diseases such as diabetes, chronic pulmonary disease, allergic disorders, etc. are at greater risk of developing "abnormalities" during exposure to composting.

Testing for these individuals:

- pulmonary function testing
- chest X-rays
- physical examinations
- history and illness monitoring

Optional tests

- complete blood counts
- erythrocyte sedimentation rates: index of ongoing inflammatory response
- liver and renal function tests
- determination of antibody to LPS and *A. fumigatus* antigens.

(4) In order to gain further insight into the etiology of gastroenteritis among wastewater workers, sera collected before and after such episodes, along with rectal swabs and stool collected during the acute phase of the illness, should be analyzed to determine the agents involved. Norwalk agent and related viruses and toxigenic or invasive *E. coli* should be included in the serologic testing. Swabs and stool should be examined for the presence of bacteria, viruses and parasites.

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(5) In order to determine if the apparent excess of leukemia deaths persists in a larger population, the Mortality Study of Chicago Metropolitan Sanitary District Workers (MSD) should be expanded by: 1) analysis of 1960-76 decedents not included in the present study, 2) extension of the study to include 1977-1982 decedents, and 3) extension of the study to include all MSD decedents prior to 1960.

(6) A mortality study of wastewater workers in another metropolitan area should be initiated to determine if an excess of deaths by leukemia has occurred in other wastewater worker populations.

(7) Since the test for urinary thioethers appears to be potentially useful as a biological indicator of chemical exposure it should be utilized in studies of other populations exposed to chemical wastes.

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SECTION 4

PROSPECTIVE HEALTH STUDY OF WORKERS ENGAGED IN THE COMPOSTING OF MUNICIPAL WASTEWATER TREATMENT PLANT SLUDGE

Personnel employed at wastewater treatment plant sludge composting operations are exposed to a variety of viable gram-negative bacteria and fungi, as well as microbial products such as endotoxin [lipopolysaccharide (LPS)] in their work environment. This investigation was designed to evaluate, by clinical, microbiological and immunological methods, the health effects related to exposure to these nonviable substances and viable microorgasisms present in dust arising from the composting of such sludge. It is a continuation, with a few modifications, of a study conducted during 1979-80 (5). Workers at sewage sludge composting facilities in Camden, NJ, Philadelphia, PA, Beltsville, MD and Washington, D.C., were selected because of their geographic closeness and the willingness of their organizations to participate in the study.

BACKGROUND

Municipal wastewaters may contain a variety of potentially pathogenic microorganisms. Conventional wastewater treatment does not completely destroy these microorganisms, many of which are concentrated in the sludge. Therefore, sludge should be stabilized by a method such as composting prior to its application on land. Composting is a thermophilic aerobic decomposition process. Heat generated during the composting process has been shown to effectively reduce the numbers of viable microorganisms present. Two types of composting processes are currently in use - - windrow and forced aeration pile systems (9,10). The windrow system consists of long, low piles which are aerated by periodic turning. The forced aeration pile system consists of a stationary compost pile constructed over a network of porous pipe attached to a blower which draws air through the pile. Temperatures in the range of 55^{o}-65^{o}C are usually attained during the composting process (9) provided the mixing or aeration is efficient. One of the most important objectives of composting is to obtain these high uniform temperatures throughout the system for sufficient duration so as to penetrate the entire mass. When this objective is fulfilled the composting process will inactivate most microorganisms including viruses (11). However the heat generated will not detoxify the LPS of gram-negative bacteria, and other potentially toxic microbial products such as aflatoxin present in the compost.

The heat generated during composting results in temperatures ideal for the proliferation of many thermophilic microorganisms such as actinomycetes, mucorales and in particular, *Aspergillus fumigatus*. Therefore, compost workers potentially may be exposed not only to the enteric pathogenic microorganisms present in raw sludge (also referred to as primary pathogens since they are capable of initiating an infection in an apparently healthy individual) but also

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to the thermophilic fungi and actinomycetes that proliferate during composting.

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Millner, Bassett and March (12) conducted extensive monitoring of airborne spores of *A. fumigatus* at compost sites at Beltsville, MD and at the Blue Plains Wastewater Treatment Plant in Washington, D.C. Using volumetric sampling techniques, these investigators demonstrated that the dispersal of fungal spores from composting sewage sludge and wood chip mixtures behaved as a Gaussian plume. A major source of airborne spores was found to be the front-end loader which was estimated to aerosolize 4.6 x 10^6 *A. fumigatus* spores/second when moving and dropping compost. The sampling instrument used was the six-stage Andersen sampler with the sampling orifice directed into the wind and with the top cone removed to collect more non-respirable particles (13). Other investigators (14) including us, have neither removed the top cone nor tilted the sampler in their sampling procedure. At the Beltsville compost site airborne concentrations of *A. fumigatus* between three and 30 meters downwind of a compost pile being agitated by a front-end loader were reported to range from 1400 to 3100 cfu/m^3. Fifteen minutes after agitation, levels were not above 39 cfu/m^3.

Clark, Rylander and Larrson have recently reported high levels of *A. fumigatus* at compost plants in Sweden which used wastewater sludge mixed with either household refuse or wood chips (15).

Aspergillus species are ubiquitous in the environment of most countries of the world. The fungus grows well on a variety of substrates, including stored hay or grain, decaying vegetation, soil, and dung. *A. fumigatus* grows well at 45°C or even higher, making it one of the most common microorganisms found at compost sites (16). *A. fumigatus*, and other species of Aspergillus have been shown to be capable of causing disease in both normal and compromised individuals. Therefore, workers involved in the composting process may be exposed to potential health risks due to their exposure to high concentrations of *A. fumigatus* spores.

The term "Aspergillosis" has been used to describe illness attributed to antigenic stimulation, colonization, or tissue invasion by *Aspergillus* species. Aspergillosis is thought to be acquired by inhalation of airborne spores. These spores (conidia) are small enough (2.5-3.0 μm for *A. fumigatus*) to reach alveoli or to gain entrance to paranasal sinuses. The disease varies in severity from an incidental, saphrophytic relationship with the host to a fulminating, fatal infection.

The dose (number of cfu), portal of entry, and the immune status of the host are thought to be major determinants in the course of the infection caused by *Aspergillus* species. Immunosupporessed patients are thought to be at a greater risk to infection by *A. fumigatus* (13,16). Serious and often fatal invasive infections caused by *A. fumigatus* have been reported in immunosuppressed patients following kidney transplanation and in patients with leukemia or lymphoma receiving chemotherapy. Individuals receiving antibiotics or adrenal cortical hormones have also been shown to have a higher incidence of mycotic infections. Additional predisposing factors to aspergillosis appear to be the presence of malignant or other debilitating disease, leukopenia or granulocytopenia, other infections, pneumonitis and underlying pulmonary disease (17).

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Exposure of atopic individuals, who have a history of asthma, to spores of *A. fumigatus* may result in a disease known as allergic bronchopulmonary aspergillosis. Colonization of the bronchi in these patients with *Aspergillus* results in episodic bronchial plugging which appears to lead to areas of sacular bronchiectasis. These patients may produce sputum plugs which often reveal fungal mycelia on microscopic examination. Laboratory abnormalities in these patients include significant eosinophilia of blood and sputum, marked elevation of total serum IgE, and serum precipitating antibody to *Aspergillus* antigens. These patients usually have an immediate type skin response to *Aspergillus* antigen. Persistent bronchopulmonary aspergillosis may result in irreversible complications such as bronchiectasis and pulmonary fibrosis.

The pathophysiology of allergic bronchopulmonary aspergillosis is thought to be mediated by a combination of both Type I and Type III immunologic reactions. IgE-sensitized mast cells in the bronchi react to antigens from *Aspergillus* colonies growing in the bronchi. These mast cells release histamine, slow-reacting substance of anaphylaxis and eosinophilic chemotactic factor leading to bronchospasm, increased permeability of the bronchial mucosa, absorption of *Aspergillus* antigen into the circulation, and pulmonary and peripheral blood eosinophilia. The absorbed *Aspergillus* antigen can react with IgG, resulting in the formation of antigen-antibody complexes and complement fixation. This in turn may lead to chronic inflammation in the bronchi and peribronchial tissues with eventual bronchial destruction, bronchiectasis, and pulmonary fibrosis.

Due to the wide distribution of *Aspergillus* species in the environment, exposure to Aspergillus must be nearly universal, but disease, either invasive or allergic, is uncommon. As indicated above, a complex interaction between host factors and the challenge dose of *Aspergillus* species spores appears to determine the course of events which follow exposure to *Aspergillus*. Reliable attack rates in populations are not available because of difficulties in diagnosis and subsequent inadequate reporting.

The dust at composting sites may also contain significant quantities of LPS derived from viable and nonviable gram-negative microorganisms which are present in sludge. In addition, the fungus *Aspergillus flavus* which produces aflatoxin, one of the most potent known human carcinogens, may increase in numbers during composting and the aflatoxin produced by this fungus may present an additional hazard for compost workers. Detroy et al. (18), have shown that the optimal conditions for aflatoxin production (i.e., moisture content, humidity, temperature, incubation time, aeration and nitrogen and carbohydrate content) are similar to conditions present in portions of the aerated compost pile (19). It has also been shown that aflatoxin is not destroyed by temperatures of 60-80°C and therefore would not be detoxified by the temperatures generated during composting (18). High concentrations of *Aspergillus* species have been found in buildings in which municipal solid waste was being processed prior to composting (20) or use as a fuel (21). In the latter *A. flavus* was the second most abundant species identified, 22,000 cfu/m^3 compared to 53,000 cfu/m^3 for *A. fumigatus*. Concentrations of aflatoxin B1 were found to be 6.7 and 17 ppb in two airborne dust samples in the refuse-derived-fuel facility. Assuming a 15 ppb concentration in the dust and based on a respirable airborne dust concentration of 2 mg/m^3, the average daily exposure to workers was estimated to be 70-80 pg day^{-1}. Agricultural workers engaged in the harvesting of

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aflatoxin-contaminated corn (22) were found to be exposed to dust containing an average of 120 ppb aflatoxin B1 in respirable dust of an average of 20 mg/m^3. The agricultural workers would accordingly inhale an estimated 6000 pg day^{-1} of respirable aflatoxin B1. The long-term health effects of chronic exposure to the combination of microbial pathogens, microbial toxins and LPS which may be present in the work environment at composting sites are uncertain.

Rylander et al., studied various parameters of acute and chronic inflammation in workers exposed to dust arising from heat-treated sludge at a sewage treatment plant in Gothenburg, Sweden (23,24,25). These investigators observed a significant elevation in immunoglobulins (IgG, IgM, and IgA), leukocytes and platelets in workers at the sewage treatment plant as compared to a group of age-matched control workers at a neighboring oil refinery. In addition, elevated levels of C-reactive protein and fibrin degradation products (FDP) were observed in significantly greater numbers of the sewage treatment plant workers as compared to the control population. CRP is an acute phase reactant that would be elevated if an individual were undergoing an inflammatory response such as could be caused by exposure on a chronic basis to an irritant such as endotoxin which was assayed by Rylander et al. (25). FDP would be expected to be elevated in the urine of an individual whose fibrinolytic system was stimulated in response to the presence of fibrin due to the activation of the coagulation system in the lung caused by the chronic inhalation of a dust such as endotoxin. Workers at the sewage treatment plant were also reported to experience the following clinical symptoms, apparently related to heavy dust exposure: a) fever, b) purulent discharge from the eyes, c) diarrhea, and d) fatigue. The investigators postulated that the serologic changes and clinical symptoms observed in the sewage treatment plant workers may be related to endotoxin which is present in the dust arising from the heat treated sludge. They expressed concern regarding the potential health risks associated with the chronic exposure to endotoxin containing dusts in the work environment.

Rylander et al. also studied the airway immune response to inhaled endotoxin in laboratory animals (26). Rats were exposed to an aerosolized solution of LPS of Escherichia coli O25:B6 daily for 10 days. The dose of LPS deposited in the lungs of each rat was estimated to be 0.3 μg per day. After the 10-day exposure, elevated levels of IgG, IgM and IgA antibodies specific for E. coli O25:B6 endotoxin were demonstrated in the sera of the exposed rats. Bronchial washings from the exposed rats contained IgG and IgA antibodies directed against the E. coli O25:B6 LPS. In addition, the bronchial lavage fluid was also reported to contain an increased number of polymorphonuclear leukocytes (PMN) following challenge with LPS. At cessation of exposure, the number of PMN's in the bronchial lavage fluid decreased and reached values comparable to those observed in control rats within three days. These observations suggested that inhalation of LPS is capable of producing an acute inflammatory response in the lungs of laboratory animals and that long-term exposure to dust containing LPS may lead to pathologic changes in the pulmonary parenchyma caused by the persistent inflammation. McGuire et al. (27) recently reported acute pulmonary inflammation in rhesus monkeys induced by intravenous infusion of purified bacterial LPS. These investigators have demonstrated the presence of an enzyme thought to be elastase derived from PMN's, which cleaved components of the Hageman factor and complement systems in pulmonary alveoli of the LPS challenged animals.

Rylander and his colleagues have extended their studies of the immune response to inhaled endotoxin to include workers exposed to cotton dust in cotton mills in England and Sweden (28). Workers with a history of exposure to cotton dust and subjective pulmonary symptoms of chest tightness were shown to have, in their nasal secretions, elevated levels of IgG and IgA antibodies specific for antigens prepared from a gram-negative bacteria isolated from cotton plants being processed in the mills. No elevation of IgG or IgA antibody levels with specificity for the antigen preparations employed were observed in nasal secretions obtained from a control population of workers with no history of exposure to cotton dust. Rylander postulated, based on his human and animal data, that chronic inhalation of endotoxin with the accompanying inflammatory response in the lungs, may play a critical role in the development of Byssinosis, a disease frequently observed in workers exposed to cotton dust over a prolonged period.

Endotoxin has been detected in airborne dust at compost plants (29), and in swine and poultry confinement facilities (30 and 31).

Dutkiewicz (32,33) conducted an immunologic survey of grain handlers in Poland who were exposed to high concentrations of the gram-negative bacterium *Erwinia herbicola* (synonym *Enterobacter agglomerans*) in their work environment. Workers exposed to dusts containing large numbers of *E. herbicola* (5×10^4 to 1×10^5 cfu/m^3) had a significantly higher frequency of serum precipitating antibody directed against *E. herbicola* antigen preparations than unexposed individuals. Furthermore, intradermal skin testing with antigens prepared from *E. herbicola* revealed a higher incidence of positive skin reactions in workers exposed to *E. herbicola* than in unexposed individuals. Grain handlers exposed to dust containing *E. herbicola* and who complained of respiratory symptoms such as cough, dyspnea, and wheezing, were shown to have a higher incidence of positive skin and precipitin reactions to *E. herbicola* antigens than asymptomatic exposed workers. This study provides further evidence to suggest that exposure to antigens of gram-negative bacteria, such as LPS, by inhalation is capable of inciting a systemic immune response and that it may play a primary role in the development of chronic pulmonary disease in exposed individuals.

Lundholm and Rylander (34) have reported the results of a study of 11 workers at a plant where municipal sewage sludge and household garbage were crushed, milled, and allowed to compost for six months. Gram-negative bacteria were reported to be present in large numbers where garbage was loaded onto the conveyor belts (18,000 cfu/m^3) and even higher near the mill outlet (25,000-500,000 cfu/m^3). Elsewhere at the plant they ranged from an average of 330 to 11,000 cfu/m^3. At the central water treatment plant levels averaged 20 cfu/m^3. Six of the 11 compost plant workers reported symptoms of nausea, headache, fever or diarrhea compared to only two of the 41 water treatment plant employees who served as controls.

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EXPERIMENTAL PROCEDURES

The clinical and serologic evaluation of workers exposed to dust at the composting site included: 1) comprehensive history, 2) physical examination and chest X-ray of selected participants, 3) illness monitoring, 4) complete blood count with differential, 5) determination by the enzyme-linked immunosorbent assay (ELISA) of IgG antibodies directed against antigen prepared from *Aspergillus fumigatus* (*AF*) and determination of antibody against *AF* species antigen by a counterimmunoelectrophoresis (CIE) method in sera obtained from the study participants, 6) determination of IgG antibodies in workers' sera directed against LPS prepared from compost by the ELISA technique, 7) pulmonary function tests, 8) determination of C3, C-reactive protein (CRP) and hemolytic complement (CH_{50}) in workers' sera, 9) determination of serum renal and liver profiles, and 10) determination of antibody directed against *Histoplasma capsulatum* in workers' sera. Health questionnaires, nose and throat cultures and sera for the serologic tests were obtained three times during the project period. Air monitoring for *AF* and other thermophilic fungi was also conducted. The scheduling of the various study elements during the Cooperative Agreement and a comparison with that during the previous study is summarized in Table 1.

Population Groups Selected

Workers in the study were divided into three exposure categories: category I - workers directly engaged in composting; category II - workers occasionally involved in composting or whose job locations are within 100 meters of a composting operation; category III - workers not involved in compost activities and whose job activities are greater than 100 meters from composting. The compost plants selected for study were the same in both the initial and the present study. In Camden, NJ the compost unit is located at the main wastewater treatment plant; the facility is operated by the Camden County Municipal Utilities Authority. In Philadelphia, PA the compost plants are located at the Northeast and Southwest Wastewater Treatment Plants and are operated by the Philadelphia Water Department. In Washington, D.C. the compost plant is located at the Blue Plains Wastewater Treatment Plant and is operated by the D.C. Department of Environmental Services. The compost facility in Beltsville, MD is located at the Beltsville Agricultural Research Center; this compost facility treats sludge produced at the Blue Plains Wastewater Treatment Plant. Permission to recruit compost-exposed employees at the Beltsville Agricultral Research Center was obtained from Maryland Environmental Services which employs most of the workers directly involved in compost-related activities at Beltsville. About one-half of the compost workers in Philadelphia and all compost workers at Blue Plains, were employees of private firms contracted by the respective municipalities on a yearly basis to perform composting functions. Workers in exposure category II were recruited from other more distant locations at and near the compost plants. Exposure category III workers in Philadelphia were located at a third wastewater treatment plant, the Southeast Plant; in Camden at the Baldwin Run Wastewater Treatment Plant and in Washington, D.C. from a wastewater pumping station and from the District of Columbia Water Services Department. The latter group was substituted for the Piscataway, MD wastewater treatment plant worker group which was included in the 1979-80 study. The Piscataway plant was at a location more than 10 miles from the nearest sludge compost plant but workers there were obviously exposed to

TABLE 1. CLINICAL, SEROLOGIC AND AIR MONITORING ELEMENTS OF COMPOST WORKERS STUDY

Study Element	Month of Study Previous Grant 1/79						Cooperative Agreement 2/81	
	1	5	7	9	12	21	23	26
Comprehensive medical and occupational history	(completed on initial visit with participant)							
Physical examination				X				
Health questionnaire (30-day recall)	X	X	X	X	X	X	X	X
Anterior nares and oropharyngeal swabs for *A. fumigatus*	X	X	X	X	X	X	X	X
Chest X-ray				X				
Complete blood count with differential	X	X	X	X	X	X	X	X
Fungal serology:								
a) ELISA method for specific IgG and IgE against *A. fumigatus*	X	X	X	X	X	X	X	X
b) CIE method for pooled *Aspergillus spp*. antigens	X	X	X	X	X	X	X	X
Determination of antibody (IgG) directed against lipopolysaccharide (LPS) prepared from compost from study cities	X	X	X	X	X	X	X	X
Skin testing with *A. fumigatus* antigen preparation				X				
Pulmonary function testing[a]	X	X	X	X	X	X	X	X
Immunochemical determination of C3B, CRP, hemolytic complement (CH_{50}) and immunoglobulins (IgM, IgG, and IgA)[b]	X	X	X	X	X	X	X	X
IgE determination, total	X							
Air monitoring[c]		X	X	X	X	X	X	X
Renal and liver profiles	X				X			X
Determination of the presence of aflatoxin B_1 and G_1 in compost						X		
Determination of antibody directed against *Histoplasma capsulatum* (H and M bands)								X

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[a] Including pre- and post-shift testing on Friday and Monday when possible.

[b] Determination of IgM, IgG and IgA performed only in 1979.

[c] Air monitoring performed at approximately same intervals as clinical trips.

wastewater aerosols. It was thought desirable to have a control group in at least one of the cities (such as D.C. water service employees) that had no occupational exposure to viable and nonviable microorganisms present in aerosols produced from wastewater. A brief description of the characteristics of the facilities from which the study participants were recruited is presented in Table 2. In addition, limited analyses were performed on specimens obtained from twenty workers recruited from Bangor and Portland, ME who were seen on one occasion during the present study and once in the early study. Each of these cities operates small wastewater treatment plant sludge composting facilities.

The number of workers in each group, their geographic distribution, and the period of time during which they were studied is summarized in Table 3.

Informed Consent

The rationale behind the study and the components of the study protocol were explained to each worker prior to his or her entering the study. A statement of informed consent (Appendix B) was signed by each worker prior to entering the study.

Socioeconomic, Work Exposure, and Medical History

Upon entering the study, each participant completed a comprehensive history (Appendix C) which covered socioeconomic status, prior work experience, prior exposure to toxic chemicals or dust, and a medical history. The comprehensive history questionnaire was administered to each worker by one of the investigators. A major portion of this questionnaire was repeated at the end of the study as a check on the reliability of the responses (Appendix D).

Illness Monitoring

During each visit, the study participants completed a short health questionnaire (Appendix E) specifically designed to determine by 30-day recall the occurrence of hypersensitivity, respiratory, gastrointestinal, and mucocutaneous disorders that might be associated with exposure to composting. This questionnaire was administered to each participant by one of the investigators. Workers were seen at locations that were generally central to workers in more than one exposure category. Thus the person administering the questionnaire was not aware of the specific exposure category assigned.

Physical Examination

During the period of the overall investigation 26 exposure category I workers, 39 exposure category II workers, and 42 exposure category III workers were given one-time physical examinations. The examinations were performed by licensed physicians. The results of the physical examination were recorded on a standard form (Appendix F). The examinations for Camden workers were performed by A. Zagoren, M.D. at the Cherry Hill Medical Center. In the Washington, D.C. area they were performed in the ad-

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TABLE 2. CHARACTERISTICS OF FACILITIES WHERE STUDY PARTICIPANTS WERE EMPLOYED

Location	Wastewater Facility		Compost Facility	
	Size	Type	Size	Date Started
Camden, NJ	30 MGD	Primary	15 T/D	5/78
" "	4 MGD	Act. Sl.[1]	None	
Philadelphia, PA	130 MGD	Act. Sl.	100 T/D	9/77
" "	136 MGD	Primary	125 T/D	6/76
" "	136 MGD	Primary[2]	None	
Washington, D.C.	300 MGD	Act. Sl.	75 T/D	2/79
" "	(Water Services)		None	
Beltsville, MD	None		15 T/D[3]	3/73
Piscataway, MD	30 MGD	Act. Sl.	None	

MGD = Million gallons per day, Primary = Primary treatment, Act. Sl. = Activated Sludge treatment and T/D = Dry tons per day.

[1] Sludge treated at 15 T/D Camden compost facility.

[2] Sludge treated at 125 T/D Philadelphia compost facility.

[3] Sludge trucked from Washington, D.C. wastewater facility.

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TABLE 3. POPULATION GROUPS PARTICIPATING IN COMPOST WORKERS STUDY

Location	Number of Participants			Duration in Study of Group*
	Compost Workers	Intermediate-Exposed	Control	
Camden	26	32	12	Jan. '79-Feb. '81
Philadelphia	32	10	13	May '79-Feb. '81
Blue Plains (Washington, D.C.)	15	67	21	March '79-Feb. '81
Beltsville, MD	11	8	0	March '79-Feb. '81
Piscataway	0	0	34	March '79-Dec. '79
D.C. Water Services	0	0	33	Sept. '80-Feb. '81

*Individual participants may have had a shorter duration in study because of attrition and because new compost workers were recruited throughout most of the study period.

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ministration building at the Blue Plains wastewater treatment plant by H. Herbert, M.D.

Chest Roentgenogram

Chest roentgenograms were obtained on 18 exposure category I workers, 26 exposure category II workers, and 34 exposure category III workers one time during the first year of the study. The chest roentgenograms were performed at hospitals and medical care facilities located geographically near each facility involved in the study. All roentegenograms were evaluated without knowledge of exposure status by J. F. Wiot, M.D., Chairman and Professor of Radiology, Department of Radiology, University of Cincinnati College of Medicine, Cincinnati, OH.

Determination of Pulmonary Function

Routine pulmonary function testing during the clinical trips was performed during the second half of the work shift. On several occasions pre and post shift testing was also performed on Fridays and the following Mondays. Results from all of the tests were used to calculate the parameters of vital capacity (FVC), forced expiratory volume in first second (FEV_1), and forced midexpiratory flow (FEF 25-75%). Pulmonary function was determined using a portable Vitalograph spirometer; and were administered by study personnel who had successfully completed a NIOSH approved course on Pulmonary Function Testing. At the time of testing the spirometer was calibrated and the barometric pressure, spirometer temperature, and date were recorded. The sex, ethnic identity, standing height, weight, and age at the time of the last birthday of each study participant was also recorded. A minimum of three "acceptable" FVC maneuvers were obtained after suitable demonstration for each participant. Evidence for an acceptable maneuver included adequate understanding, unhesitating start, apparent maximal effect with smooth continuous exhalation, and absence of cough, glottis closure, early termination, leak, and no mouthpiece obstruction by tongue or teeth. Furthermore, the FVC and FEV_1 of the best 2 of 3 acceptable tracings did not vary by more than ± 5 percent of reading or ± 0.1 liters, whichever was greater.

Complete Blood Count and Differential

Blood samples for complete blood counts (CBC) and differential were collected in tubes containing EDTA as an anticoagulant from each study participant during each visit. Determination of the CBC and differential were performed in laboratories located geographically near each facility participating in the study.

Renal and Liver Function Profiles

Blood for determination of renal and liver function were collected in tubes containing no anticoagulant. These samples were obtained annually from each study participant. After obtaining the blood, the blood was allowed to clot and the serum was removed. The serum samples were frozen on dry ice and samples were maintained at -20°C until the determinations were performed. The following determinations of liver and renal function were performed by the Department of Laboratory Medicine, University of Cincinnati College of Medicine: alkaline phosphatase, gamma GT, albumin, total and direct bilirubin, SGPT, SGOT, Na, K, Cl, total CO_2, glucose, BUN, creatinine.

Determination of Antibody Against Aspergillus species Antigens by CIE

Serum for determination of antibody directed against *Aspergillus* species antigens was collected from all study participants during each visit as described above. Precipitating antibody directed against *A. fumigatus*, *A. flavus*, *A. carneus*, and *A. niger* antigens (Aspergillin, Meridian Diagnostics, Cincinnati, OH) in the serum of the study participants was measured semi-quantitatively by titration of antibody using the CIE technique (35). Positive controls were goat antiserum against the *Aspergillus* species antigens and serum from a patient with allergic aspergillosis (patient serum provided by L. Bernstein, M.D.).

Detection of Antibody Directed Against Histoplasma capsulatum in Sera by CIE

The antigen used for detection of antibody in sera was a mycelial phase culture filtrate of *Histoplasma capsulatum* (Histoplasmin, Meridian Diagnostic, Inc.). Antibody in workers sera directed against histoplasmin was detected by CIE (35). A control serum, raised in goats, containing antibodies against the "H" and "M" antigens of histoplasmin was placed in a well adjacent to the serum to be tested. The presence of a M precipitin band was considered presumptive evidence for infection with *H. capsulatum*.

Determination of Allergy to Aspergillus fumigatus of the Immediate Type

Immediate hypersensitivity to antigens of *A. fumigatus* was determined by the scratch test. Workers were requested to avoid all medications, particularly antihistamines and sympathomimetic drugs for at least 24 hours prior to skin testing. At the time skin testing was performed a physician was present and injectable epinephrine and a tourniquet was available should a systemic anaphylactic reaction occur following application of the antigen. Prior to testing the skin area to be scratched was cleaned with alcohol and the area was allowed to dry. A clean sterile Robinson Scarifier was used to disrupt the outer layers of epidermis down to the germinal layer of the skin on the volar surface of the forearm. One drop of a 1:10 (weight/volume) dilution of *A. fumigatus* antigen solution (Hollister-Stier, Downers Grove, IL) was applied to the scarified skin. The drop was rubbed into the scratch with a wooden toothpick. One drop of the diluent used in the *A. fumigatus* antigen solution was applied to a second area of scarified skin as a control. The scratch test sites were examined for evidence of erythema and wheal formation 15 and 30 minutes after the application of antigen and diluent solutions. A positive reaction was considered to be an urticarial wheal with surrounding erythema larger than the control site. A ruler was used to measure the size of the reaction and the reactions were graded as summarized in Table 4.

TABLE 4. GRADING OF SKIN TEST FOR IMMEDIATE HYPERSENSITIVITY AGAINST *ASPERGILLUS FUMIGATUS* ANTIGENS

Grade	Erythema (mm)	Wheal (mm)
0	<5	<4
±	5-10	5-10
1+	11-20	5-10
2+	21-30	5-10
3+	31-40	10-15[a]
4+	40	15[b]

[a] Or with pseudopods.

[b] Or with many pseudopods.

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Preparation of Antigens from Aspergillus fumigatus

A. fumigatus ATCC was grown in sabouraud dextrose broth (Difco Laboratories, Detroit, MI) at 31°C for 5 weeks. The mycelium was separated from the culture medium by Buchner filtration followed by Seitz filtration to remove any viable fungal elements. The filtrate was concentrated 8X by ultra filtration using an Amicon PM 10 membrane (Amicon Corporation, Lexington, MA). The concentrated culture filtrate was precipitated with eight volumes of acetone at 4°C (36). The precipitate was pelleted by centrifugation at 12,000 x g at 4°C and the precipitate was washed with acetone at 4°C. The precipitate was dissolved in distilled water, lyophilized, and stored at -60°C. This antigen preparation was used for detection of antibody in sera using the ELISA technique.

Preparation of Lipopolysaccharide from Composted Sewage Sludge

Samples of cured screened compost were obtained from the Camden, NJ and Blue Plains compost facilities. LPS was prepared from 500 gm aliquots of the compost by the phenol-water extraction procedure of Westphal and Jann (37). The combined water extracts were precipitated with ethanol. The ethanol precipitated LPS was dissolved in distilled water and ultracentrifuged at 110,000 x g for 3 hours at 4°C. The resulting pellet was dissolved in distilled water, lyophilized and stored at -60°C. The LPS preparations were used for detection of antibody in sera using the ELISA technique.

Determination of Antibody in Serum Directed Against A. fumigatus and LPS Antigens Using ELISA

The ELISA used in this study was a solid phase immunoassay as described by Engvall and Perlmann (38) and modified for detection of antibodies directed against LPS by Bruins et al. (39). The optimal concentration of the *A. fumigatus* antigen for coating polystyrene cuvettes was determined by the method of Engvall and Perlmann (38) and was found to be 500 µg/ml of lyophilized antigen. The concentration of LPS used to coat polystyrene cuvettes was determined in a similar manner and was found to be 1 µg/ml for LPS prepared from both Camden and Blue Plains compost. Serum to be assayed for specific antibody was diluted 1:100 in 0.01M phosphate-buffered saline (PBS), pH 7.4 and 200 µl of the diluted serum was added to the antigen coated polystyrene cuvettes. After washing the cuvettes, alkaline phosphate labeled goat antiserum against human IgG (Miles Biochemicals, Elkhart, IN) was added to the cuvettes, the cuvettes were incubated at room temperature for 3 hours and then washed with distilled water. Two-tenths ml of a solution of p-nitrophenyl phosphate (Sigma 104 phosphatase substrate, 1 mg/ml, Sigma Chemical Co. ST. Louis, MO) in 0.05M sodium carbonate and 0.001M magnesium chloride buffer, pH 9.8 was added to each cuvette. After 90 minutes of incubation at 37°C, 1.0 ml of 1 N sodium hydroxide was added to stop the reaction and the absorbance (OD) of the solutions were read at 400 nm. Every time the ELISA was performed, a sample of sera pooled from ten healthy normal volunteers (laboratory personnel) was included. Values obtained on different days were normalized by dividing the OD of the workers' sera samples by the OD of the pooled serum. All determinations were performed in triplicate.

Determination of CRP, C3, IgM, IgA, and IgG Concentrations in Serum by Radial Immunodiffusion

Single radial immunodiffusion was performed by a minor modification of the method of Mancini et al. (40). For assaying the concentration of the B antigen of C3, agarose (1%) dissolved in veronal buffer ($u = 0.05$, $pH = 8.6$) containing 0.04M EDTA was used. For assays of Ig levels and CRP, agarose (1%) dissolved in PBS saline, pH 7.0 was used. An appropriate dilution of antiserum in agarose was poured into plastic plates and stored at 4°C for up to two days. For assays of the B antigen of C3, CRP, and Ig levels, thirty 2 mm diameter wells were made in each plate, and 3 µl of serum were delivered into each well. The unknowns and serial dilutions of the standard serum for the protein being measured were placed in the wells and diffusion was carried out at room temperature for 18 hours. All determinations were performed in duplicate. Antiserum and normal reference serum for the B antigen of C3 was generously supplied by Dr. A. Bjornson. Antiserum and normal reference serum for Ig and CRP were obtained from Behring Diagnostics, Sommerville, NJ.

Determination of Hemolytic Complement

Hemolytic complement was determined by the method of Kabat and Mayer (41). Results were expressed as the units/ml of serum which resulted in 50% lysis of sensitized sheep erythrocytes (CH_{50} units/µl).

Determination of IgE Concentration in Serum by Radioimmunoassay

The concentration of total IgE in sera obtained from workers participating in this study was determined by radioimmunoassay using the Pharmacia Diagnostics (Piscataway, NJ) Phadebas IgE PRIST kit. The assay was performed in accordance with the manufacturer's instructions. All determinations were performed in duplicate.

Legionella pneumophila Antibody

Antibody to L. pneumophila was determined using the indirect fluorescent antibody assay and antigen from serogroups 1 through 4 in the laboratory of Dr. Calvin C. Linnemann, Jr. These determinations were added to the protocol because of the possibility that this organism could be present in sludge processed at sludge compost sites.

Semiquantitative Determination of Numbers of Aspergillus fumigatus Colony Forming Units in Anterior Nares and Throat Cultures

Cultures of the throat and anterior nares of the workers participating in the study were obtained with a dry cotton-tipped applicator (Culturette II, Marian Scientific Corp., Kansas City, MO). The cultures were stored on dry ice until processed. The numbers of A. fumigatus contained on the cotton tipped applicator were determined by immersing the applicator in 2.0

ml of sterile saline. The applicator was vortexed vigorously for 60 seconds to elute any fungal elements contained on the applicator. After elution, the number of A. fumigatus contained on the applicator was determined by dilution plate count methods on Czapek-Dox Bile agar plates containing streptomycin, chloramphenicol and penicillin (Difco Laboratories).

Environmental Monitoring

Viable particle collection from air samples was performed using the six-stage Andersen cascade impactor designed for that purpose. Air was drawn through the samplers by 12 volt D.C. pumps, which were powered by 12 volt motorcycle batteries. The pumps, attached to an assembled sampler loaded with petri dishes containing agar, were calibrated against a dry gas meter to pull one cubic foot of air per minute (CFM), as recommended by the manufacturer. The samplers were mounted on tripods such that samples were collected at a height of five feet, which approximate the breathing zone of the average worker. Sampling times were adjusted in an attempt to obtain colony numbers which were optimal for counting. The volume of air sampled was calculated from the sampling time and the flow rate of the pumps. Total colony counts for bacterial and fungal plates were obtained by direct colony count, unless excessive colony numbers precluded this procedure. If colony numbers precluded counting all colonies, the colonies on 1/4 or 1/2 the plate were counted and the count was multiplied by the appropriate number to obtain a total plate count.

Bacterial samples were collected on Trypticase soy agar (TSA) manufactured by Baltimore Biological Laboratories (BBL), Cockeysville, MD. The medium was prepared according to the manufacturers instructions, autoclaved at 121°C for 15 minutes, cooled to 45-50°C and dispensed into petri dishes. Prior to use, TSA plates were incubated at 36°C for 24-48 hours to detect contamination and minimize surface moisture due to condensation.

Fungal samples were collected on modified Czapek-Dox medium. The medium was prepared by adding 35 g of Czapek-Dox broth (Difco Laboratories, Detroit, MI), 20 g agar (Difco), and 15 g Oxgall (Matheson, Coleman and Bell, Cincinnati, OH) to 1000 ml distilled water, adjusting the pH to 7.3 and autoclaving at 121°C for 15 minutes. Prior to dispensing, the medium was cooled to 45-50°C and 50 μg/ml Streptomycin, 50 μg/ml Chloramphenicol and 20 units/ml Pencillin were added to retard bacterial growth. These plates were incubated at room temperature or occasionally at 36°C to minimize moisture.

Aerosol samples obtained on TSA plates were shipped directly (within 24 hours) to the Research Surgical Bacteriology Laboratory, Department of Surgery, University of Cincinnati College of Medicine, where they were incubated at 35°C for 24 hours. At the end of the incubation period, total bacterial counts on the TSA plates were determined; the plates were then replicate plated onto three selective media: KF streptococcal agar (BBL), M-FC agar (BBL), and M-Endo agar (BBL) (42).

KF streptococcal agar is a selective medium which supports the growth of fecal streptococci (Lancefield's serological groups D and Q) while in-

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hibiting the growth of most gram-negative and other gram-positive bacteria. The presence of pink/red colonies after 48 hours at 36°C is indicative of fecal streptococci. All growth on KF streptococcal agar was re-replicated to Bile-Esculin agar (Difco) and tested for catalase activity. Gram-positive cocci which grew as brown/black colonies on Bile-Esculin agar, and which failed to decompose a three percent solution of hydrogen peroxide, were considered to be confirmed fecal streptococci.

The purpose of replication onto M-FC agar was to determine the presence or absence of fecal coliforms. These plates were incubated at 44.5°C for 24 hours and the blue to blue green colonies were transferred to a Lauryl sulfate broth (BBL) which was incubated 24-48 hours at 37°C and to EC broth (BBL) which was incubated for 24 hours at 44.5°C. Growth with gas in these media confirmed the presence of fecal coliforms.

In order to determine total coliform counts, the TSA plates were replicated onto M-Endo agar (BBL) and incubated at 37°C for 24 hours. The colonies with a green sheen were picked to Lauryl sulfate broth and Brilliant green bile broth (BBL). These media were incubated at 37°C for 48 hours, ± 3 hours. Growth with gas confirmed the presence of coliforms.

Fungal plates, upon reaching the laboratory, were incubated at 44.5°C for 48 hours and total plate counts were performed. The microorganisms were separated into _A. fumigatus_ and "other thermophilic microorganisms" on the basis of microscopic examination and colony color and morphology.

Detailed information on media used and other aspects of the microbiological analyses described above can be found in Appendix C-5.

Extraction of Aflatoxin from Compost Samples

Compost samples for the determination of aflatoxin were homogenized, extracted, and defatted by the recommended procedure for the extraction of small quantities of aflatoxin (43). The presence of aflatoxin was determined by thin layer chromatography (TLC) on silica gel G coated glass plates in a solvent system of chloroform and acetone (9:1). Aflatoxin concentrations were estimated by visual comparison of fluorescence against analytical standards of aflatoxin B_1 and G_1 (Sigma Chemical Co.). Due to the possibility that other chloroform soluble compounds were extracted from the compost, thereby masking the presence of the aflatoxin on TLC, an alternative method for isolating and quantitating aflatoxin was also evaluated. The chloroform extractable material obtained from compost was chromatographed over an activated silica gel column using various organic solvent mixtures. The presence of aflatoxin in the eluate was determined by fluorimetry.

RESULTS

Illness

Illness symptoms were obtained from interviews with study participants at the time of the clinical visits. Workers in all exposure categories were seen at the same time. The symptoms experienced during the 30 days prior to the interview were analyzed cross-sectionally by visit date, by geographical area (Camden-Philadelphia area, Washington, D.C. metropolitan area, and all areas combined), and by symptom category. Workers in all areas were combined for one of the comparisons in order to increase the likelihood of detecting actual difference in illness rates among the work groups. The importance of population size can be realized by calculating the number of workers that are needed per exposure group to detect various possible difference in illness rates. The exposure group size needed for comparing rates of 70% with 30%, 50% with 30% and 40% with 30% are 40, 143 and 515, respectively. Statistical analyses were performed using the multi-variate chi-square method where age, race and experience group were included as covariables. The symptom categories were: total (Tables 5 and 6), upper respiratory (Table 7), lower respiratory (Table 8), non-respiratory (Table 9), diarrhea (Table 10), skin irritation (Table 11) and burning eyes (Table 12). Comparisons were made between number of workers with symptoms and number of workers without symptoms. Because a high proportion of workers experienced at least one of the total array of symptoms, the total illness data was also analyzed according to the number of workers with two or more symptoms and the number of workers with one or no symptoms (Table 6). During a special visit to the Washington, D.C. and Beltsville, MD groups to perform Friday and Monday pre- and post shift pulmonary function tests, illness questionaires were also administered (Table 13). In October 1980, the questionnaire was also used for a group of workers at two locations in Maine (Table 14). For only one comparison was $p \leq 0.01$; in November 1980 for the combined areas, 3-5 times as many workers in the high and intermediate-exposed categories had burning eyes than did control workers ($p = 0.002$) (Table 12). For the next visit similar differences were reported ($p = 0.09$). A summary of all comparisons where $p \leq 0.10$ is presented in Table 15. For five comparisons of non-respiratory symptoms there were differences with $p \leq 0.10$. In all cases the compost workers had fewer symptoms. On three occasions skin irritation symptoms for workers in the combined areas showed differences with more compost workers having symptoms than the control workers. On one occasion, December 1980 (Washington, D.C. and Beltsville), more compost and intermediate exposed workers had symptoms of diarrhea than did control workers. Overall, the only symptoms where the suggestion of a pattern of increased symptoms among exposed workers occurred was for skin irritation and burning eyes.

Physical Examinations

In an attempt to minimize variability in the performance of physical examinations, physicians participating in the study were provided with a standard form to record the results of the examination. Abnormal findings which may be related to compost exposure were limited to the eyes, ears, nose, and skin. These abnormalities were observed more frequently in the compost and intermediate exposure groups than in the non-exposed controls ($p = 0.0001$) (Table 16). Evidence of acute or chronic inflammation of the nose (engorged inferior turbinates) was present in 5 compost workers, 7 workers in the intermediate exposure group and in none of the controls ($p = 0.01$). Nasal disorders were only observed in workers from Camden, NJ. Skin disorders were reported in 3 compost workers, 8 intermediately exposed

TABLE 5. COMPARISONS AMONG EXPOSURE GROUPS OF NUMBER OF WORKERS WITH ONE OR MORE ILLNESS SYMPTOMS

		Camden-Phila. Area		Wash. D.C. Metro Area		All Areas Combined	
Date	Exposure Group	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms
5/79	I	11	2	8	2	19	4
	II	9	3	25	11	34	14
	III	7	1	22	12	29	13
		$X^2_2 = 0.20$	$p = 0.90$	$X^2_2 = 0.80$	$p = 0.67$	$X^2_2 = 0.87$	$p = 0.64$
7/79	I	16	9	5	5	21	14
	II	12	2	10	9	22	6
	III	17	1	9	10	26	11
		$X^2_2 = 2.54$	$p = 0.28$	$X^2_2 = 1.00$	$p = 0.61$	$X^2_2 = 1.80$	$p = 0.41$
8/79	I	11	9	12	3	23	12
	II	6	8	16	2	22	10
	III	14	2	19	6	33	8
		$X^2_2 = 4.22$	$p = 0.12$	$X^2_2 = 1.03$	$p = 0.60$	$X^2_2 = 2.16$	$p = 0.34$
9/79	I	17	11	7	5	24	16
	II	13	7	23	3	36	10
	III	14	4	21	13	35	17
		$X^2_2 = 0.34$	$p = 0.85$	$X^2_2 = 0.50$	$p = 0.78$	$X^2_2 = 2.54$	$p = 0.28$
12/79	I	28	6	2	5	30	11
	II	17	4	3	1	20	5
	III	14	1	16	3	30	4
		$X^2_2 = 0.24$	$p = 0.89$	$X^2_2 = .064$	$p = .073$	$X^2_2 = 1.31$	$p = 0.52$

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TABLE 5 (continued)

Date	Exposure Group	Camden-Phila. Area # Wkrs. With Symptoms	Camden-Phila. Area # Wkrs. Without Symptoms	Wash. D.C. Metro Area # Wkrs. With Symptoms	Wash. D.C. Metro Area # Wkrs. Without Symptoms	All Areas Combined # Wkrs. With Symptoms	All Areas Combined # Wkrs. Without Symptoms
9/80	I	32	6	7	5	40	11
	II	12	4	8	14	29	10
	III	13	1	3	0	16	1
		$X_2^2 = 1.08$	$p = 0.58$	$X_2^2 = 0.21$	$p = 0.90$	$X_2^2 = 2.47$	$p = 0.29$
11/80	I	30	5	7	2	37	7
	II	11	8	16	1	27	9
	III	11	1	20	13	31	14
		$X_2^2 = 5.13$	$p = 0.08$	$X_2^2 = 0.51$	$p = 0.78$	$X_2^2 = 3.31$	$p = 0.19$
2/81	I	30	9	4	3	34	12
	II	11	2	13	5	24	7
	III	11	1	11	6	22	7
		$X_2^2 = 0.03$	$p = 0.99$	$X_2^2 = 0.99$	$p = 0.61$	$X_2^2 = 0.09$	$p = 0.96$

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TABLE 6. COMPARISONS AMONG EXPOSURE GROUPS OF WORKERS WITH TWO OR MORE ILLNESS SYMPTOMS

		Camden-Phila. Area		Wash. D.C. Metro Area		All Areas Combined	
Date	Exposure Group	# Wkrs. With 2 or More Symptoms	# Wkrs. With 1 or No Symptoms	# Wkrs. With 2 or More Symptoms	# Wkrs. With 1 or No Symptoms	# Wkrs. With 2 or More Symptoms	# Wkrs. With 1 or No Symptoms
5/79	I	8	5	2	8	10	13
	II	6	6	18	18	24	24
	III	6	2	17	17	23	19
		$X_2^2 = 1.01$	$p = 0.60$	$X_2^2 = 1.11$	$p = 0.57$	$X_2^2 = 0.86$	$p = 0.65$
7/79	I	8	17	5	5	13	22
	II	6	8	8	6	14	14
	III	9	9	5	14	14	23
		$X_2^2 = 1.40$	$p = 0.50$	$X_2^2 = 0.37$	$p = 0.83$	$X_2^2 = 1.16$	$p = 0.56$
8/79	I	8	12	10	5	18	17
	II	5	9	14	4	19	13
	III	9	7	17	8	26	15
		$X_2^2 = 0.74$	$p = 0.69$	$X_2^2 = 0.04$	$p = 0.98$	$X_2^2 = 0.93$	$p = 0.63$
9/79	I	11	17	5	7	16	24
	II	10	10	18	8	28	18
	III	8	10	15	9	23	29
		$X_2^2 = 0.56$	$p = 0.76$	$X_2^2 = 0.51$	$p = 0.73$	$X_2^2 = 3.68$	$p = 0.16$
12/79	I	22	12	0	7	22	19
	II	13	8	2	2	15	10
	III	10	5	15	4	25	9
		$X_2^2 = 0.08$	$p = 0.96$	$X_2^2 = 1.85$	$p = 0.40$	$X_2^2 = 1.77$	$p = 0.41$

(continued)

TABLE 6 (continued)

Date	Exposure Group	Camden-Phila. Area # Wkrs With 2 or More Symptoms	Camden-Phila. Area # Wkrs. With 1 or No Symptoms	Wash. D.C. Metro Area # Wkrs. With 2 or More Symptoms	Wash. D.C. Metro Area # Wkrs. With 1 or No Symptoms	All Areas Combined # Wkrs. With 2 or More Symptoms	All Areas Combined # Wkrs. With 1 or No Symptoms
9/80	I	26	12	4	8	30	21
	II	11	5	14	8	25	14
	III	7	7	2	1	9	8
		$X_2^2 = 1.56$	$p = 0.46$	$X_2^2 = 1.67$	$p = 0.43$	$X_2^2 = 1.19$	$p = 0.55$
11/80	I	19	10	4	5	23	21
	II	10	9	15	2	25	11
	III	8	4	14	19	22	23
		$X_2^2 = 0.35$	$p = 0.84$	$X_2^2 = 3.46$	$p = 0.18$	$X_2^2 = 3.13$	$p = 0.21$
2/81	I	25	14	2	5	27	19
	II	7	6	13	5	20	11
	III	7	5	6	11	13	16
		$X_2^2 = 0.31$	$p = 0.86$	$X_2^2 = 3.06$	$p = 0.22$	$X_2^2 = 2.81$	$p = 0.25$

TABLE 7. COMPARISON OF UPPER RESPIRATORY ILLNESS SYMPTOMS AMONG EXPOSURE GROUPS

		Camden-Phila. Area		Wash. D.C. Metro Area		All Areas Combined	
Date	Exposure Group	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms
5/79	I	7	6	4	6	11	12
	II	7	5	18	18	25	23
	III	6	2	17	17	23	19
		$X_2^2 = 1.09$	$p = 0.58$	$X_2^2 = 0.13$	$p = 0.94$	$X_2^2 = 0.18$	$p = 0.91$
7/79	I	12	13	3	7	15	20
	II	4	6	6	8	14	14
	III	10	8	6	13	16	21
		$X_2^2 = 0.16$	$p = 0.92$	$x_2^2 = 0.54$	$p = 0.76$	$X_2^2 = 0.30$	$p = 0.86$
8/79	I	9	11	10	5	19	16
	II	6	8	12	6	18	14
	III	8	8	15	10	23	18
		$X_2^2 = 0.03$	$p = 0.99$	$X_2^2 = 0.94$	$p = 0.62$	$X_2^2 = 0.01$	$p = 1.00$
9/79	I	11	17	2	10	13	27
	II	11	9	15	11	26	20
	III	9	9	16	18	25	27
		$X_2^2 = 1.12$	$p = 0.57$	$X_2^2 = 2.02$	$p = 0.36$	$X_2^2 = 4.27$	$p = 0.12$
12/79	I	26	8	0	7	26	15
	II	14	7	3	1	17	8
	III	7	8	14	5	21	13
		$X_2^2 = 4.14$	$p = 0.13$	$X_2^2 = 2.75$	$p = 0.25$	$X_2^2 = 0.91$	$p = 0.63$

(continued)

TABLE 7 (continued)

Date	Exposure Group	Camden-Phila. Area # Wkrs. With Symptoms	Camden-Phila. Area # Wkrs. Without Symptoms	Wash. D.C. Metro Area # Wkrs. With Symptoms	Wash. D.C. Metro Area # Wkrs. Without Symptoms	All Areas Combined # Wkrs. With Symptoms	All Areas Combined # Wkrs. Without Symptoms
9/80	I	25	13	6	6	31	20
	II	11	5	15	7	26	13
	III	10	4	2	1	12	5
		$X^2_2 = 0.25$	$p = 0.88$	$X^2_2 = 0.23$	$p = 0.89$	$X^2_2 = 0.86$	$p = 0.65$
11/80	I	24	12	3	6	27	18
	II	9	10	12	5	21	15
	III	7	5	14	19	21	24
		$X^2_2 = 1.14$	$p = 0.57$	$X^2_2 = 2.37$	$p = 0.31$	$X^2_2 = 2.21$	$p = 0.33$
2/81	I	27	12	4	4	31	16
	II	9	4	13	5	22	9
	III	7	5	10	7	17	12
		$X^2_2 = 0.73$	$p = 0.69$	$X^2_2 = 1.51$	$p = 0.47$	$X^2_2 = 1.55$	$p = 0.46$

TABLE 8. COMPARISON OF LOWER RESPIRATORY ILLNESS SYMPTOMS AMONG EXPOSURE GROUPS

		Camden-Phila. Area		Wash. D.C. Metro Area		All Areas Combined	
Date	Exposure Group	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms
5/79	I	5	8	1	9	6	17
	II	3	9	8	28	11	37
	III	2	6	5	29	7	35
		$X^2_2 = 0.37$	$p = 0.83$	$X^2_2 = 0.29$	$p = 0.59$	$X^2_2 = 0.85$	$p = 0.65$
7/79	I	5	20	2	8	7	28
	II	3	11	1	13	4	24
	III	3	15	3	16	6	31
		$X^2_2 = 0.17$	$p = 0.92$	$X^2_2 = 1.18$	$p = 0.55$	$X^2_2 = 0.38$	$p = 0.83$
8/79	I	4	16	1	14	5	30
	II	2	13	4	14	6	26
	III	3	13	7	18	10	31
		$X^2_2 = 0.01$	$p = 0.99$	$X^2_2 = 1.18$	$p = 0.55$	$X^2_2 = 1.28$	$p = 0.53$
9/79	I	7	21	1	11	8	32
	II	4	16	7	19	11	35
	III	0	18	9	25	9	43
		$X^2_2 = 2.44$	$p = 0.30$	$X^2_2 = 2.63$	$p = 0.27$	$X^2_2 = 0.65$	$p = 0.72$
12/79	I	9	25	1	6	10	31
	II	4	17	0	4	4	21
	III	6	9	7	12	13	21
		$X^2_2 = 1.56$	$p = 0.46$	$X^2_2 = 1.35$	$p = 0.84$	$X^2_2 = 2.70$	$p = 0.26$

(continued)

TABLE 8 (continued)

Date	Exposure Group	Camden-Phila. Area # Wkrs. With Symptoms	Camden-Phila. Area # Wkrs. Without Symptoms	Wash. D.C. Metro Area # Wkrs. With Symptoms	Wash. D.C. Metro Area # Wkrs. Without Symptoms	All Areas Combined # Wkrs. With Symptoms	All Areas Combined # Wkrs. Without Symptoms
9/80	I	13	25	2	7	15	36
	II	7	9	7	15	14	25
	III	3	11	0	3	3	14
		$X^2_2 = 1.32$	$p = 0.52$	$X^2_2 = 0.55$	$p = 0.76$	$X^2_2 = 1.93$	$p = 0.38$
11/80	I	10	26	4	5	14	31
	II	5	14	6	11	11	25
	III	5	7	8	25	13	32
		$X^2_2 = 1.09$	$p = 0.58$	$X^2_2 = 0.38$	$p = 0.83$	$X^2_2 = 0.05$	$p = 0.98$
2/81	I	14	25	2	6	16	31
	II	2	11	4	14	6	25
	III	3	9	3	14	6	23
		$X^2_2 = 0.44$	$p = 0.80$	$X^2_2 = 0.49$	$p = 0.78$	$X^2_2 = 2.68$	$p = 0.26$

TABLE 9. COMPARISON OF NON-RESPIRATORY ILLNESS SYMPTOMS AMONG EXPOSURE GROUPS

		Camden-Phila. Area		Wash. D.C. Metro Area		All Areas Combined	
Date	Exposure Group	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms
5/79	I	7	6	5	5	12	11
	II	7	5	20	16	27	21
	III	6	2	17	17	23	19
		$X_2^2 = 1.90$	$p = 0.39$	$X_2^2 = 0.90$	$p = 0.64$	$X_2^2 = 0.61$	$p = 0.74$
7/79	I	9	16	5	5	14	21
	II	7	7	9	5	16	12
	III	14	4	8	11	22	15
		$X_2^2 = 4.95$	$p = 0.08$	$X_2^2 = 0.65$	$p = 0.72$	$X_2^2 = 2.96$	$p = 0.23$
8/79	I	9	11	7	8	16	19
	II	5	9	14	4	19	13
	III	13	3	17	8	30	11
		$X_2^2 = 4.51$	$p = 0.10$	$X_2^2 = 1.06$	$p = 0.59$	$X_2^2 = 5.69$	$p = 0.06$
9/79	I	12	16	7	5	19	21
	II	11	9	19	7	30	16
	III	11	7	16	18	27	25
		$X_2^2 = 0.88$	$p = 0.64$	$X_2^2 = 0.06$	$p = 0.97$	$X_2^2 = 2.53$	$p = 0.28$
12/79	I	17	17	1	6	18	23
	II	14	7	2	2	16	9
	III	13	2	10	9	23	11
		$X_2^2 = 3.61$	$p = 0.16$	$X_2^2 = 1.26$	$p = 0.53$	$X_2^2 = 4.54$	$p = 0.10$

(continued)

Table 9 (continued)

Date	Exposure Group	Camden-Phila. Area # Wkrs. With Symptoms	Camden-Phila. Area # Wkrs. Without Symptoms	Wash. D.C. Metro Area # Wkrs. With Symptoms	Wash. D.C. Metro Area # Wkrs. Without Symptoms	All Areas Combined # Wkrs. With Symptoms	All Areas Combined # Wkrs. Without Symptoms
9/80	I	26	12	2	6	30	21
	II	11	5	16	1	23	16
	III	10	4	3	3	13	4
		$X^2_2 = 0.06$	$p = 0.97$	$X^2_2 = 4.67$	$p = 0.10$	$X^2_2 = 1.72$	$p = 0.42$
11/80	I	23	12	3	6	26	18
	II	9	10	16	1	25	11
	III	10	2	13	20	23	22
		$X^2_2 = 2.73$	$p = 0.25$	$X^2_2 = 6.96$	$p = 0.04$	$X^2_2 = 1.97$	$p = 0.37$
2/81	I	24	15	2	5	26	20
	II	7	6	10	8	17	14
	III	7	5	6	11	13	16
		$X^2_2 = 0.04$	$p = 0.98$	$X^2_2 = 1.40$	$p = 0.50$	$X^2_2 = 1.60$	$p = 0.45$

TABLE 10. COMPARISON OF DIARRHEA SYMPTOMS AMONG EXPOSURE GROUPS

		Camden-Phila. Area		Wash. D.C. Metro Area		All Areas Combined	
Date	Exposure Group	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms
5/79	I	4	9	4	6	8	15
	II	2	10	8	28	10	38
	III	2	5	5	29	7	34
		$X^2_2 = 0.27$	$p = 0.87$	$X^2_2 = 1.35$	$p = 0.51$	$X^2_2 = 1.95$	$p = 0.38$
7/79	I	1	24	3	7	4	31
	II	3	11	3	11	6	22
	III	5	13	0	19	5	32
		$X^2_2 = 3.99$	$p = 0.14$	$X^2_2 = 1.46$	$p = 0.48$	$X^2_2 = 0.99$	$p = 0.61$
8/79	I	1	19	5	10	6	29
	II	1	13	5	13	6	26
	III	5	11	2	23	7	34
		$X^2_2 = 2.64$	$p = 0.27$	$X^2_2 = 3.57$	$p = 0.17$	$X^2_2 = 0.03$	$p = 0.99$
9/79	I	3	25	2	10	5	35
	II	2	18	5	21	7	39
	III	3	15	2	32	5	47
		$X^2_2 = 0.44$	$p = 0.80$	$X^2_2 = 1.16$	$p = 0.56$	$X^2_2 = 0.70$	$p = 0.70$
12/79	I	4	30	0	7	4	37
	II	5	15	2	2	7	17
	III	3	12	3	16	6	28
		$X^2_2 = 1.72$	$p = 0.42$	$X^2_2 = 3.00$	$p = 0.22$	$X^2_2 = 3.07$	$p = 0.22$

(continued)

TABLE 10 (continued)

		Camden-Phila. Area		Wash. D.C. Metro Area		All Areas Combined	
Date	Exposure Group	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms
9/80	I	4	34	2	10	23	28
	II	2	14	3	19	27	12
	III	3	11	2	1	9	8
		$X_2^2 = 2.26$	$p = 0.32$	$X_2^2 = 2.32$	$p = 0.31$	$X_2^2 = 2.71$	$p = 0.26$
11/80	I	6	30	0	9	6	39
	II	3	16	3	14	6	30
	III	3	8	1	32	4	40
		$X_2^2 = 1.19$	$p = 0.55$	$X_2^2 = 0.81$	$p = 0.67$	$X_2^2 = 0.44$	$p = 0.80$
2/18	I	7	32	1	7	8	39
	II	3	10	4	14	7	24
	III	3	9	2	15	5	24
		$X_2^2 = 0.78$	$p = 0.68$	$X_2^2 = 0.10$	$p = 0.95$	$X_2^2 = 0.04$	$p = 0.98$

TABLE 11. COMPARISON OF SKIN IRRITATION AMONG EXPOSURE GROUPS

		Camden-Phila. Area		Wash. D.C. Metro Area		All Areas Combined	
Date	Exposure Group	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms
5/79	I	3	10	0	10	3	20
	II	1	11	3	32	4	43
	III	0	8	1	33	1	41
		$X^2_2 = 1.85$	$p = 0.40$	$X^2_2 = 1.32$	$p = 0.52$	$X^2_2 = 2.12$	$p = 0.35$
7/79	I	1	24	0	10	1	34
	II	1	13	1	13	2	26
	III	2	16	1	18	3	34
		$X^2_2 = 0.75$	$p = 0.69$	$X^2_2 = 0.34$	$p = 0.84$	$X^2_2 = 1.04$	$p = 0.60$
8/79	I	4	16	1	14	5	30
	II	1	13	1	17	2	30
	III	3	13	4	21	7	34
		$X^2_2 = 1.26$	$p = 0.53$	$X^2_2 = 1.39$	$p = 0.50$	$X^2_2 = 1.87$	$p = 0.39$
9/79	I	7	21	1	11	8	32
	II	3	17	5	21	8	38
	III	1	17	2	32	3	49
		$X^2_2 = 3.84$	$p = 0.15$	$X^2_2 = 1.39$	$p = 0.50$	$X^2_2 = 5.43$	$p = 0.07$
12/79	I	2	32	0	7	2	39
	II	2	19	0	4	2	23
	III	2	13	1	18	3	31
		$X^2_2 = 0.79$	$p = 0.67$	$X^2_2 = 0.49$	$p = 0.78$	$X^2_2 = 0.21$	$p = 0.90$

(continued)

TABLE 11 (continued)

Date	Exposure Group	Camden-Phila. Area # Wkrs. With Symptoms	Camden-Phila. Area # Wkrs. Without Symptoms	Wash. D.C. Metro Area # Wkrs. With Symptoms	Wash. D.C. Metro Area # Wkrs. Without Symptoms	All Areas Combined # Wkrs. With Symptoms	All Areas Combined # Wkrs. Without Symptoms
9/80	I	11	27	2	10	13	38
	II	0	16	2	20	2	37
	III	1	13	0	3	1	16
		$X_2^2 = 3.12$	$p = 0.21$	$X_2^2 = 0.15$	$p = 0.93$	$X_2^2 = 5.16$	$p = 0.08$
11/80	I	4	32	1	8	5	40
	II	2	17	6	11	8	28
	III	3	9	2	31	5	40
		$X_2^2 = 1.64$	$p = 0.44$	$X_2^2 = 1.92$	$p = 0.38$	$X_2^2 = 2.41$	$p = 0.30$
2/81	I	8	31	0	8	8	39
	II	1	12	4	14	5	26
	III	1	11	0	17	1	28
		$X_2^2 = 0.02$	$p = 0.99$	$X_2^2 = 1.09$	$p = 0.58$	$X_2^2 = 5.42$	$p = 0.07$

TABLE 12. COMPARISON OF BURNING EYES SYMPTOMS AMONG EXPOSURE GROUPS

Date	Exposure Group	Camden-Phila. Area # Wkrs. With Symptoms	Camden-Phila. Area # Wkrs. Without Symptoms	Wash. D.C. Metro Area # Wkrs. With Symptoms	Wash. D.C. Metro Area # Wkrs. Without Symptoms	All Areas Combined # Wkrs. With Symptoms	All Areas Combined # Wkrs. Without Symptoms
5/79	I	2	10	1	9	3	19
	II	4	8	6	30	10	38
	III	3	5	10	24	13	29
		$X_2^2 = 1.45$	$p = 0.48$	$X_2^2 = 0.24$	$p = 0.89$	$X_2^2 = 2.65$	$p = 0.27$
7/79	I	6	19	1	9	7	28
	II	4	10	3	11	7	21
	III	5	13	5	14	10	27
		$X_2^2 = 0.18$	$p = 0.91$	$X_2^2 = 0.76$	$p = 0.68$	$X_2^2 = 0.59$	$p = 0.75$
8/79	I	4	16	3	12	7	28
	II	3	11	4	14	7	25
	III	5	11	8	17	13	28
		$X_2^2 = 0.48$	$p = 0.79$	$X_2^2 = 0.48$	$p = 0.79$	$X_2^2 = 1.51$	$p = 0.47$
9/79	I	5	23	0	12	5	35
	II	4	16	7	19	11	35
	III	6	12	8	26	14	38
		$X_2^2 = 1.16$	$p = 0.56$	$X_2^2 = 3.28$	$p = 0.19$	$X_2^2 = 2.89$	$p = 0.24$
12/79	I	9	25	0	7	9	32
	II	4	17	1	3	5	20
	III	2	13	3	16	5	29
		$X_2^2 = 0.15$	$p = 0.93$	$X_2^2 = 0.91$	$p = 0.63$	$X_2^2 = 0.77$	$p = 0.68$

(continued)

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TABLE 12 (continued)

		Camden-Phila. Area		Wash. D.C. Metro Area		All Areas Combined	
Date	Exposure Group	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms	# Wkrs. With Symptoms	# Wkrs. Without Symptoms
9/80	I	15	23	1	11	16	35
	II	4	12	6	16	10	29
	III	5	9	1	2	6	11
		$X_2^2 = 0.26$	$p = 0.88$	$X_2^2 = 1.62$	$p = 0.45$	$X_2^2 = 0.53$	$p = 0.77$
11/80	I	10	26	1	8	11	34
	II	6	13	10	7	16	20
	III	2	9	2	31	4	40
		$X_2^2 = 0.59$	$p = 0.74$	$X_2^2 = 2.70$	$p = 0.26$	$X_2^2 = 12.37$	$p = 0.002$
2/81	I	15	24	0	8	15	32
	II	4	9	5	13	9	22
	III	2	10	2	15	4	25
		$X_2^2 = 0.30$	$p = 0.86$	$X_2^2 = 1.97$	$p = 0.37$	$X_2^2 = 4.88$	$p = 0.09$

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TABLE 13. COMPARISON OF ILLNESS SYMPTOMS AMONG WASHINGTON, D.C. AND BELTSVILLE STUDY GROUPS - DECEMBER 1980*

Illness	Exposure Group	# Workers With Symptoms	# Workers Without Symptoms
Total	I	2	5
	II	3	10
	III	3	7
		$\chi^2_2 = 0.13$	p = 0.94
Total**	I	3	4
	II	4	9
	III	5	5
		$\chi^2_2 = 0.12$	p = 0.97
Upper Respiratory	I	5	2
	II	4	9
	III	6	4
		$\chi^2_2 = 1.98$	p = 0.37
Lower Respiratory	I	6	2
	II	8	5
	III	7	3
		$\chi^2_2 = 0.10$	p = 0.95
Non-Respiratory	I	3	4
	II	4	9
	III	5	5
		$\chi^2_2 = 0.10$	p = 0.95
Diarrhea	I	3	5
	II	2	11
	III	0	10
		$\chi^2_2 = 5.77$	p = 0.06
Skin Irritation	I	0	8
	II	4	9
	III	1	9
		$\chi^2_2 = 2.88$	p = 0.24
Burning Eyes	I	1	7
	II	5	8
	III	3	7
		$\chi^2_2 = 1.20$	p = 0.55

*Illness questionnaire to workers participating in Friday-Monday pre and post shift pulmonary function testing.

**Workers with 2 or more symptoms compared with those with one or no symptoms.

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TABLE 14. COMPARISON OF ILLNESS SYMPTOMS AMONG EXPOSURE GROUPS IN MAINE (OCTOBER 1980)

Symptom(s)	Exposure Group	# Workers With Symptoms	# Workers Without Symptoms
Total	I	6	0
	II	4	0
	III	5	1
		$X^2 = 0.83$	$p = 0.66$
Total*	I	5	1
	II	4	0
	III	4	0
		$X^2 = 0.78$	$p = 0.68$
Upper Respiratory	I	5	1
	II	4	0
	III	5	1
		$X^2 = 0.20$	$p = 0.90$
Lower Respiratory	I	1	5
	II	0	4
	III	3	3
		$X^2 = 3.06$	$p = 0.22$
Diarrhea	I	0	6
	II	1	3
	III	2	4
		$X^2 = 3.28$	$p = 0.19$
Skin Irritation	I	2	4
	II	0	4
	III	0	5
		$X^2 = 2.22$	$p = 0.33$
Burning Eyes	I	0	5
	II	1	3
	III	2	4
		$X^2 = 1.76$	$p = 0.41$

*Workers with 2 or more symptoms compared with workers with 1 or no symptoms.

TABLE 15. SUMMARY OF COMPARISONS OF INCIDENCE OF ILLNESS SYMPTOMS AMONG STUDY GROUPS ($p \leq 0.10$)

Illness Symptom	Area	Date	Differences*	p
Total	Camden-Phila.	11/80	III, I, II	0.08
Non-Respiratory	Camden-Phila.	7/79	III, II, I	0.08
Non-Respiratory	Camden-Phila.	8/79	III (I, II)	0.10
Non-Respiratory	Wash. Metro	11/80	II (I, III)	0.04
Non-Respiratory	Combined	8/79	III (II, I)	0.06
Non-Respiratory	Combined	12/79	(III, II) I	0.10
Skin Irritation	Combined	9/79	(I, II) III	0.07
Skin Irritation	Combined	9/80	I (II, III)	0.08
Skin Irritation	Combined	2/81	(I, II) III	0.07
Burning Eyes	Combined	11/80	(I, II) III	0.002
Burning Eyes	Combined	2/81	(I, II) III	0.09
Diarrhea	Wash. D.C. and Beltsville	12/80	I, II, III	0.06

*Exposure group listed in relative order with group with highest prevalence listed first. Groups within a parenthesis have similar prevalences.

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TABLE 16. RESULTS OF PHYSICAL EXAMINATIONS

Abnormal Findings	Compost Workers n = 26	Intermediate-Exposed n = 39	Control n = 42
Evidence of acute or chronic inflammation of eyes and nose:	(number of workers with abnormal finding)		
Orbitopalpebral grooves	0	1	0
Inferior turbinates* (engorged)	5	7	0
Evidence of acute or healed ear infection	2	2	0
Number of workers with one or more of the following skin abnormalities**	3	8	0
Evidence of active or healed skin abscesses, carbuncles or furuncles	1	4	0
Evidence of other cutaneous infections	1	3	0
Other abnormalities of skin	1	1	0
Number of workers with one or more abnormal finding***	8	14	0

*p = 0.01, **p = 0.006, ***p = 0.0001 (by Fisher's Exact Test and Bonferroni Probabilities)

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workers; no abnormalities were observed in the control workers ($p = 0.006$). Two compost and 2 intermediately exposed workers had evidence of acute or healed ear infections; 3 of these workers had developed acute ear infections during the period of time they were employed at compost sites. One of the compost workers developed a chronic ear infection with *Aspergillus niger* about two years after starting compost work which has persisted for several years; the infection has resulted in destruction of the right ear drum.

The interpretation of the physical examination results should be treated with caution because of the relatively few workers involved and the geographic differences in the abnormal findings (Table 17) with more abnormal findings detected among Camden, NJ workers than in those in Washington, D.C. area, including all of the nasal disorders (inferior turbinates). It should be noted that the Camden, NJ intermediate-exposed workers were in general working in close proximity with the compost workers and shared some lunch and locker rooms with them. These close working conditions did not exist for intermediate-exposed workers in the Washington, D.C. area. The physical examinations in the two areas were also conducted by different physicians.

Chest Roentgenogram

Chest X-rays were obtained and evaluated from 74 participants during the first year of the study. Only two workers had abnormalities of the lungs or pleural space. One compost worker had evidence of diffuse interstitial lung disease; this worker also had the chronic fungal infection of his right ear, described above. The worker was a non-smoker and denied any history of disease or occupational exposure other than composting which might account for the abnormalities. One control worker had evidence of a non-occupational abnormality.

Pre/Post Shift Pulmonary Function Testing

Pulmonary function studies were performed on workers in the three exposure groups before and after a normal work shift on Friday and repeated the following Monday to evaluate the impact of exposure to the environment at the compost site on lung function (44). A forced vital capacity (FVC), forced expired volume in the first second (FEV_1), and forced expiratory flow (FEF_{25-75}) were measured using a Vitalograph Spirometer; this instrument was chosen because of its ability to be easily transported and its accuracy (45). All tracings were 6 seconds in duration. FVC is a measure of the volume of air which can be exhaled after a maximal inspiration; FEV_1 is a measure of the volume of air exhaled during the first second, and FEF_{25-75} measured the 50% of forced vital capacity after the first 25%. FEF_{25-75} is sensitive to early changes in air flow in small airways.

A total of 98 sets of Monday/Friday data, collected between May 1979 and January 1982 from 98 individuals, were analyzed (Table 18). Forty sets of tests were conducted on group I (compost workers), 29 sets of tests were conducted on subjects in group II and 29 sets of tests were conducted on subjects in group III (non-exposed). Race, age and sex data and smoking history are displayed in Table 19. The majority of workers in all 3 groups

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TABLE 17. GEOGRAPHIC DISTRIBUTION OF PHYSICAL EXAMINATION FINDINGS - CAMDEN, NJ WORKERS (C) AND WASHINGTON, D.C. AREA WORKERS (W)

	Compost Workers		Intermediate-Exposed		Control	
Abnormal Findings	C n = 8	W n = 18	C n = 14	W n = 25	C n = 4	W n = 38
Evidence of acute or chronic inflammation of eyes and nose:						
Orbitopalpebral grooves	0	0	1	0	0	0
Inferior turbinates (engorged)	5	0	7	0	0	0
Evidence of acute or healed ear infection	1	1	0	2	0	0
Skin:						
Evidence of active or healed skin abscesses, carbuncles or furuncles	1	0	2	2	0	0
Evidence of other cutaneous infections	0	1	3	0	0	0
Other abnormalities of skin	1	0	1	0	0	0
Totals	8	2	14	4	0	0

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TABLE 18. DATES OF PRE-POST SHIFT PULMONARY FUNCTION TESTING

Date	Exposure Group 1	Exposure Group 2	Exposure Group 3	Total
	(number of workers tested)			
May 1979	10	6	5	21
September 1979	9	9	0	18
December 1980	4	14	5	23
November 1981	4	0	19	23
January 1982	13	0	0	13
	40	29	29	98

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TABLE 19. DEMOGRAPHIC DATA AND SMOKING HISTORY OF PARTICIPANTS IN PRE AND POST SHIFT PULMONARY FUNCTION TESTING

	Race		Sex	
	White	Non-White	Male	Female
Group 1	19	21	39	1
Group 2	15	14	26	3
Group 3	7	22	29	0

	Age			Smoking History*		
	Range	Median	Mean	Non-smoker	Former smoker	Smoker
Group 1	21-62	45.5	43	13	4	19
Group 2	27-73	32.5	37	12	6	11
Group 3	26-58	39	39	10	15	4

*Smoking history not known for 4 people in group 1.

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were male. In group III 77% of the workers were non-white. All other variables are fairly evenly distributed.

Using a t-test measure, the differences between 18 various pairings of values were examined (Table 20). All comparisons for which $p \leq 0.10$ are presented in Table 21. Results demonstrate statistically significant differences at $p \leq .05$ only between the FVC tracings from Friday evening and Monday morning in group I, the compost workers, ($p = 0.04$) with the average FVC being 1.06 liter higher on Friday evening than on Monday morning. No statistically significant results ($p \leq 0.05$) are observable between any other paired values in group I or in group II or group III.

These preliminary results suggest that the forced vital capacity in compost workers recorded on Fridays is higher than the value on Mondays, and that non-exposure to compost over a 2-day weekend may be a factor, as this difference is not demonstrated in workers with less intense or no exposure to compost. Such results need further and careful evaluation before conclusions can be drawn, as these results represent small populations. Individual subject values need to be evaluated before type and extent of pulmonary function changes, if any, can be identified.

Eosinophil and White Blood Cell Counts

Comparisons of white cell count, eosinophiles (%) and absolute eosinophile count data between exposure groups were performed for each date specimens were collected, for the last available data for each individual. Because of the variable number of visits per worker we were not able to use analysis of repeated measures for these and other comparisons of time series data without discarding the majority of the data set. We therefore also elected to combine all of the data without regard to visit date for the purpose of performing an overall analysis of each data set. Results are presented in Table 22 for Camden-Philadelphia area participants, in Table 23 for Washington, D.C. metropolitan area participants and for all study participants in the combined areas in Table 24. Of the total of 90 comparisons made, 13 were significant ($p \leq 0.05$) compared to 5 expected by chance alone. In the Camden-Philadelphia area the only significant difference was in February 1981 where the eosinophile percentage was higher in group I than in Group II ($p = 0.04$); however, since the group III (control group) values were almost as high as for group I, the difference detected does not appear to be compost related.

In the Washington, D.C. metropolitan area (Table 23) significant differences were detected in white cell counts in December 1979, September 1980, November 1980, for last available data and for all data combined. However, for two of these comparisons (December 1979 ($p = 0.04$) and November 1980 ($p = 0.02$)) the intermediate exposure group (II) had the highest levels. For November 1980 ($p = 0.02$), the last available data ($p = 0.008$) and for all visits combined ($p = 0.05$) the differences are consistent with a compost-related effect. Eosinophile (%) levels were different for all data combined ($p = 0.05$) with compost workers (I) having the highest levels and controls (III) the lowest. For eosinophile count, there were significant differences in May 1979 ($p = 0.04$) and for all data combined ($p = 0.04$) with compost workers again being highest and controls lowest.

TABLE 20. PRE AND POST SHIFT PULMONARY FUNCTION COMPARISON FOR WHICH STATISTICAL ANALYSES PERFORMED

Test	Results compared
Forced Vital Capacity (FVC)	Friday pre-shift and Friday post-shift
	Friday pre-shift and Monday pre-shift
	Friday pre-shift and Monday post-shift
	Friday post-shift and Monday post-shift
	Friday post-shift and Monday pre-shift
	Monday pre-shift and Monday post-shift
Forced Expired Volume in one second (FEV_1)	Friday pre-shift and Friday post-shift
	Friday pre-shift and Monday pre-shift
	Friday pre-shift and Monday post-shift
	Friday post-shift and Monday post-shift
	Friday post-shift and Monday pre-shift
	Monday pre-shift and Monday post-shift
Forced Expiratory Flow (FEF_{25-75})	Friday pre-shift and Friday post-shift
	Friday pre-shift and Monday pre-shift
	Friday pre-shift and Monday post-shift
	Friday post-shift and Monday post-shift
	Friday post-shift and Monday pre-shift
	Monday pre-shift and Monday post-shift

TABLE 21. PULMONARY FUNCTION TESTING COMPARISONS FOR WHICH $P \leq 0.10$

Exposure Group	Test	Result	P-value
Compost workers	FEV_1	Fri. A.M.-Fri. P.M. = -0.74	0.06
Compost workers	FVC_1	Fri. P.M.-Mon. A.M. = 1.09	0.04
Compost workers	FEF_{25-75}	Mon. A.M.-Mon. P.M. = 2.04	0.09
Controls	FVC_1	Fri. P.M.-Mon. P.M. = -1.43	0.05

TABLE 22. COMPARISONS OF EOSINOPHILE AND WHITE BLOOD CELL COUNTS AMONG EXPOSURE GROUPS: CAMDEN-PHILADELPHIA AREA, 1979-1981

		White Cell Count per cu mm			Eosinophiles %			Eosinophile Count per cu mm		
Date	Exposure Group	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
1-3/79	I	7808	732	(13)	1.86	0.91	(7)	157.0	71.9	(7)
1-3/79	II	8025	659	(16)	2.67	0.80	(9)	225.7	63.4	(9)
1-3/79	III	8733	761	(12)	4.25	0.85	(8)	356.9	67.3	(8)
5/79	I	7289	488	(27)	2.27	0.36	(20)	158.4	36.7	(20)
5/79	II	7860	567	(20)	2.08	0.46	(12)	182.2	47.3	(12)
5/79	III	7424	507	(25)	2.45	0.36	(20)	189.9	36.7	(20)
7/79	I	7130	358	(30)	2.95	0.41	(20)	174.9	24.4	(20)
7/79	II	6950	385	(26)	2.44	0.43	(18)	173.9	25.8	(18)
7/79	III	6852	409	(23)	3.00	0.51	(13)	206.1	30.3	(13)
9/79	I	7410	316	(30)	3.68	0.49	(19)	265.0	33.2	(19)
9/79	II	7233	354	(24)	3.10	0.46	(21)	227.1	31.6	(21)
9/79	III	7121	398	(19)	3.29	0.57	(14)	222.4	38.7	(14)
12/79	I	7838	338	(34)	2.42	0.34	(24)	188.3	26.5	(24)
12/79	II	7576	430	(21)	3.08	0.48	(12)	249.8	37.5	(12)
12/79	III	7831	492	(16)	2.64	0.45	(14)	189.9	34.7	(14)
9/80	I	8485	610	(39)	2.39	0.21	(39)	193.4	16.7	(39)
9/80	II	7867	777	(24)	2.72	0.27	(24)	210.2	21.2	(24)
9/80	III	7477	1056	(13)	2.38	0.37	(13)	157.5	28.9	(13)
11/80	I	7540	289	(35)	2.37	0.24	(36)	179.6	20.0	(35)
11/80	II	7553	392	(19)	1.82	0.33	(21)	144.6	27.2	(19)
11/80	III	7609	516	(11)	2.46	0.44	(11)	192.4	35.7	(11)
2/81	I	7705	276	(38)	2.78*	0.32	(37)	218.1	27.6	(37)
2/81	II	8179	674	(14)	1.75*	0.28	(14)	149.8	32.6	(14)
2/81	III	7840	572	(10)	2.73	0.30	(10)	215.8	31.8	(10)
					* p = 0.04					
Last Avail-able*	I	8012	546	(57)	2.73	0.25	(56)	211.8	20.9	(55)
	II	7770	322	(44)	2.35	0.21	(44)	188.6	18.4	(44)
	III	7224	345	(28)	3.08	0.34	(24)	218.2	23.9	(24)
All Visits Com-bined	I	7678	167	(247)	2.61	0.12	(203)	195.7	8.9	(202)
	II	7596	154	(164)	2.47	0.14	(130)	193.8	11.9	(129)
	III	7503	208	(129)	2.82	0.19	(103)	208.0	15.3	(103)

*Last available data for each participant used in comparison.

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TABLE 23. COMPARISONS OF EOSINOPHILE AND WHITE BLOOD CELL COUNTS AMONG EXPOSURE GROUPS: WASHINGTON, D.C. METROPOLITAN AREA, 1979-1981

		White Cell Count per cu mm			Eosinophiles %			Eosinophile Count per cu mm		
Date	Exposure Group	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
1-3/79	I	6893	491	(14)	2.71	0.49	(12)	186.7	31.5	(12)
1-3/79	II	6782	218	(71)	2.32	0.20	(71)	152.3	13.2	(68)
1-3/79	III	6898	287	(41)	2.17	0.27	(41)	149.5	17.1	(41)
5/79	I	6480	426	(15)	2.95	0.44	(15)	190.3*	37.1	(15)
5/79	II	6088	238	(48)	2.48	0.25	(48)	149.0	13.6	(48)
5/79	III	6364	249	(44)	2.06	0.26	(44)	125.1*	15.6	(44)
								*p = 0.04		
7/79	I	7145	492	(11)	2.88	0.47	(11)	197.2	31.4	(11)
7/79	II	6271	356	(21)	1.94	0.35	(20)	124.5	23.3	(20)
7/79	III	6396	314	(27)	2.41	0.30	(27)	149.0	20.1	(27)
9/79	I	6856	513	(16)	2.63	0.39	(15)	177.2	30.0	(15)
9/79	II	6622	342	(36)	2.13	0.26	(35)	136.6	19.7	(35)
9/79	III	6753	324	(40)	2.14	0.25	(36)	146.8	19.4	(36)
12/79	I	6265	553	(17)	2.77	0.35	(15)	173.4	25.2	(15)
12/79	II	6615*	250	(60)	2.31	0.18	(59)	150.1	12.7	(59)
12/79	III	5768*	279	(37)	2.18	0.25	(29)	131.3	18.1	(29)
		*p = 0.04								
9/80	I	7573*	476	(15)	2.05	0.36	(15)	147.3	25.1	(15)
9/80	II	6871+	388	(24)	2.34	0.29	(23)	159.3	20.3	(23)
9/80	III	5794*,+	254	(36)	2.37	0.24	(35)	143.9	16.4	(35)
		*p = 0.001,+p = 0.02								
11/80	I	7463	564	(8)	2.18	0.49	(9)	170.7	38.9	(8)
11/80	II	7686*	322	(22)	2.08	0.32	(21)	157.8	24.0	(21)
11/80	III	6613*	298	(30)	2.25	0.27	(30)	149.1	20.1	(30)
		*p = 0.02								
2/81	I	7800	827	(4)	1.90	0.72	(3)	138.3	40.1	(3)
2/81	II	7533	390	(18)	2.39	0.33	(14)	170.8	18.6	(14)
2/81	III	6847	401	(17)	2.17	0.36	(11)	140.5	20.1	(11)

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TABLE 23 (continued)

Date	Exposure Group	White Cell Count per cu mm			Eosinophiles %			Eosinophile Count per cu mm		
		Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
Last Available	I	7329*	398	(28)	2.81	0.32	(26)	184.9	20.2	(26)
	II	6822$^+$	188	(100)	2.35	0.13	(99)	156.8	9.4	(99)
	III	6143*,$^+$	158	(97)	2.41	0.14	(96)	148.2	8.8	(96)
		*p = 0.002 +p = 0.008								
All Visits Combined	I	6930*	201	(100)	2.58*	0.18	(95)	175.7*,$^+$	12.5	(94)
	II	6698$^+$	106	(301)	2.29	0.08	(292)	149.7*	5.4	(289)
	III	6395*,$^+$	104	(273)	2.22*	0.10	(255)	142.2$^+$	6.8	(255)
		* p = 0.02 $^+$ p = 0.05			* p = 0.05			* p = 0.04 + p = 0.008		

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BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

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TABLE 24. COMPARISONS OF EOSINOPHILE AND WHITE BLOOD CELL COUNTS AMONG EXPOSURE GROUPS IN COMBINED AREAS, 1979-1981

		White Cell Count per cu mm			Eosinophiles %			Eosinophile Count per cu mm		
Date	Exposure Group	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
1-3/79	I	7333	408	(27)	2.39	0.43	(19)	175.8	30.5	(19)
1-3/79	II	7010	227	(87)	2.36	0.21	(80)	160.9	15.1	(77)
1-3/79	III	7313	291	(53)	2.51	0.27	(49)	183.4	19.0	(49)
5/79	I	7000	328	(42)	2.56	0.26	(35)	172.0	21.7	(35)
5/79	II	6609	258	(68)	2.40	0.22	(60)	155.6	16.5	(60)
5/79	III	6748	256	(69)	2.18	0.21	(64)	145.4	16.0	(64)
7/79	I	7134	285	(41)	2.93	0.30	(31)	182.8	19.3	(31)
7/79	II	6647	266	(47)	2.18	0.27	(38)	147.9	17.4	(38)
7/79	III	6606	258	(50)	2.60	0.27	(40)	167.5	17.0	(40)
9/79	I	7217	283	(46)	3.22	0.31	(34)	226.3*	22.8	(34)
9/79	II	6867	247	(60)	2.49	0.24	(56)	170.5	17.8	(56)
9/79	III	6871	250	(59)	2.46	0.26	(50)	167.9*	18.8	(50)
							*p = 0.05			
12/79	I	7314*	286	(51)	2.55	0.24	(39)	182.6	17.9	(39)
12/79	II	6864	227	(81)	2.44	0.18	(71)	166.9	13.3	(71)
12/79	III	6391*	281	(53)	2.33	0.22	(43)	150.4	17.1	(43)
		*p = 0.02								
9/80	I	8231*	406	(54)	2.30	0.19	(54)	180.5	13.8	(54)
9/80	II	7369	431	(48)	2.53	0.20	(47)	185.3	14.8	(47)
9/80	III	6241*	426	(49)	2.38	0.20	(48)	147.6	14.7	(48)
		*p = 0.001								
11/80	I	7526	252	(43)	2.33	0.22	(45)	178.0	17.3	(43)
11/80	II	7624*	258	(41)	1.95	0.23	(41)	151.5	18.0	(40)
11/80	III	6880*	258	( )	2.30	0.23	(41)	160.7	17.8	(41)
		*p = 0.04								
2/81	I	7714	273	(42)	2.71	0.30	(40)	212.1	25.7	(40)
2/81	II	7816	376	(32)	2.07	0.22	(28)	160.3	18.7	(28)
2/81	III	7069	296	(27)	2.42	0.25	(22)	174.7	19.6	(22)
Last Available	I	7787*+	381	(85)	2.76	0.20	(82)	203.2*,+	15.6	(81)
	II	7125*§	168	(147)	2.35*	0.11	(143)	166.6*,+	8.7	(143)
	III	6365+§	149	(122)	2.54	0.13	(120)	162.2+	8.8	(120)
		*p = 0.04 +p = 0.0001 §p = 0.01			*p = 0.05			*p = 0.02 +p = 0.01		
All Visits Combined	I	7462*,+	133	(347)	2.60*	0.10	(298)	189.3*,+	7.28	(296)
	II	7015*	89	(465)	2.35*	0.07	(422)	163.3*	5.32	(418)
	III	6751+	100	(402)	2.39	0.09	(359)	161.1+	6.75	(358)
		*p = 0.003 +p = 0.0001			*p = 0.03			* p = 0.004 + p = 0.003		

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For combined areas (Table 24) there were five significant differences in white cell count comparisons, two in eosinophile (%) comparisons and three in eosinophile count. All of these differences were consistent with a compost effect except in one eosinophile (%) comparison where group II was lower than group III.

The differences in white cell counts and the increased eosinophile count among the three groups are suggestive of an inflammatory response in the workers engaged in composting.

Impact of Exposure to Compost on Renal and Hepatic Function

Blood urea nitrogen (BUN) and serum creatinine determinations were used to evaluate the renal function of workers in the three exposure groups in the Camden-Philadelphia area and the Washington, D.C. area. Of the total of 101 comparisons made differences ($p \leq 0.05$) were found for 21 compared to 5 expected by chance alone. As shown in Table 25, BUN values for the controls in both geographic areas were highest in February 1981. For group sizes of 20 each, standard error of 1.5, differences of 5 units could be detected at $p = 0.05$ and power of 0.90. For the last available data and for all data combined creatinine levels were highest in the exposure group (I) in the Washington, D.C. metropolitan area. For the combined areas (Table 26) BUN levels were different among the exposure groups for four comparisons, however on one of the occasions (February 1981) the control group had the highest values. With groups of 20 each, standard errors of 0.05, differences of 0.2 units could be detected at $p = 0.05$ and power = 0.90. The overall lack of consistency in the results of these two tests is indicative of there being no compost-related effect.

Results of comparisons involving the liver profile parameters, alkaline phosphatase, and the serum transaminase enzymes SGPT, SGOT and gamma GT (SGGT) are presented in Tables 27 and 28. Significant differences for the first three parameters all involved situations where either the control or the intermediate-exposed group had the highest levels. For SGGT, however, the compost group had the highest levels in the Washington, D.C. area in January-March 1979 with the control group being the lowest. Similar differences were detected for all visits combined in the Washington, D.C. area and for the combined areas in May 1979.

Results of comparison of three other parameters included in the liver profile, albumin, total bilirubin and direct bilirubin, are presented in Tables 29 and 30. For the Washington, D.C. area albumin values were highest in the exposed group and lowest in the control group for the last available data and for all visits combined (Table 29) but for two other comparisons the opposite was the case. Similarly total bilirubin was highest in the control or intermediate group for five comparisons: February 1981 and last available data in the Camden-Philadelphia area, May 1979 and February 1981 in the Washington, D.C. area and February 1981 for all groups combined.

Compost-related effects do not seem to have been present for any of the renal and liver parameters with the possible exception of SGGT.

TABLE 25. COMPARISONS OF BUN AND CREATININE LEVELS AMONG EXPOSURE GROUPS, 1979 AND 1981

Date	Exposure Group	BUN Mean	BUN Std. Error	BUN (n)	Creatinine Mean	Creatinine Std. Error	Creatinine (n)
Camden-Phila. Area							
1-3/79	I	15.7	1.4	(13)	0.84	0.05	(14)
1-3/79	II	15.1	1.4	(14)	0.83	0.05	(14)
1-3/79	III	16.3	1.7	(9)	0.93	0.07	(9)
5/79	I	19.1	1.7	(13)	1.25	0.10	(13)
5/79	II	15.7	2.5	(6)	1.27	0.14	(6)
5/79	III	14.3	1.7	(13)	1.15	0.10	(12)
2/81	I	15.0*	0.7	(37)			
2/81	II	15.4	1.2	(13)			
2/81	III	18.3*	1.4	(10)			
		*p = 0.04					
Last Available Data	I	15.8	0.7	(47)	1.04	0.15	(47)
	II	15.6	0.8	(36)	1.03	0.17	(36)
	III	15.9	1.0	(22)	1.46	0.21	(22)
All Visits Combined[a]	I	16.1	0.5	(82)	1.02	0.02	(83)
	II	15.7	0.8	(51)	1.00	0.04	(51)
	III	16.6	0.8	(43)	1.29	0.24	(42)
Wash. D.C. Area							
1-3/79	I	11.9	1.1	(10)	0.83	0.12	(10)
1-3/79	II	12.8	0.5	(61)	0.89	0.05	(64)
1-3/79	III	12.5	0.6	(35)	0.84	0.06	(36)
5/79	I	12.0	2.4	(3)	0.93	0.09	(3)
5/79	II	14.3	1.1	(15)	1.06	0.04	(15)
5/79	III	13.1	1.1	(14)	1.04	0.04	(14)
9/79	I	14.2	1.6	(5)	1.08	0.09	(5)
9/79	II	12.6	0.8	(20)	1.03	0.04	(20)
9/79	III	14.4	0.7	(25)	1.06	0.04	(25)
2/81	I	13.9	1.0	(8)	0.88	0.06	(8)
2/81	II	12.4*	0.7	(17)	0.90	0.04	(17)
2/81	III	15.0*	0.7	(15)	0.91	0.04	(15)
		*p = 0.01					

(continued)

TABLE 25 (continued)

Date	Exposure Group	BUN Mean	BUN Std. Error	BUN (n)	Creatinine Mean	Creatinine Std. Error	Creatinine (n)
Last	I	14.2	0.7	(22)	1.39*+	0.15	(22)
Available	II	12.8	0.4	(84)	0.97*	0.08	(84)
Data	III	13.6	0.4	(79)	0.97+	0.08	(80)
					*p = 0.02 +p = 0.02		
All	I	13.7	0.6	(39)	1.19*,+	0.09	(39)
Visits	II	13.0	0.3	(136)	0.94*	0.05	(139)
Combined[a]	III	13.5	0.3	(116)	0.95+	0.05	(117)
					*p = 0.02 +p = 0.03		

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[a] Includes data from visits not listed individually because of small group sizes.

TABLE 26. COMPARISONS OF BUN AND CREATININE LEVELS AMONG EXPOSURE GROUPS: COMBINED AREAS, 1979 and 1981

		BUN			Creatinine		
Date	Exposure Group	Mean	Std. Error	(n)	Mean	Std. Error	(n)
1-3/79	I	14.0	0.9	(23)	0.83	0.07	(24)
1-3/79	II	13.2	0.5	(75)	0.88	0.04	(78)
1-3/79	III	13.3	0.6	(44)	0.86	0.05	(45)
5/79	I	17.8*	1.6	(16)	1.19	0.07	(16)
5/79	II	14.7	1.3	(21)	1.12	0.06	(21)
5/79	III	13.7*	0.8	(27)	1.09	0.06	(26)
		*p = 0.02					
9/79	I	14.2	1.5	(6)	1.00	0.08	(6)
9/79	II	12.6	0.8	(20)	1.03	0.05	(20)
9/79	III	14.7	0.7	(26)	1.07	0.04	(26)
2/81	I	14.8	0.5	(45)	0.98	0.15	(45)
2/81	II	13.7*	0.7	(30)	0.99	0.19	(30)
2/81	III	16.3*	1.0	(25)	1.35	0.20	(25)
		*p = 0.02					
Last Available Data	I	15.3*	0.5	(69)	1.15	0.10	(69)
	II	13.7*	0.4	(120)	0.98	0.08	(120)
	III	14.1	0.4	(101)	1.08	0.08	(102)
		*p = 0.01					
All Visits Combined[a]	I	15.4*	0.4	(121)	1.07	0.08	(122)
	II	13.7*	0.3	(187)	0.96	0.02	(190)
	III	14.3	0.3	(159)	1.04	0.07	(159)
		*p = 0.002					

[a] Includes data from visits not listed individually because of small group sizes.

TABLE 27. COMPARISON OF ALKALINE PHOSPHATASE AND TRANSAMINASE LEVELS AMONG EXPOSURE GROUPS, 1979 AND 1981

Groups and Date	Exposure Group	Alkaline Phosphatase			SGPT			SGOT			Gamma GT		
		Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
Camden-Phila. Area													
1-3/79	I	53.4	5.4	(14)	22.6	4.7	(14)	24.2	4.7	(14)	15.1	15.1	(14)
1-3/79	II	53.6	5.2	(15)	34.6	4.5	(15)	25.8	4.6	(15)	34.5	15.1	(14)
1-3/79	III	55.5	6.4	(10)	27.1	5.5	(10)	33.1	5.6	(10)	56.0	17.8	(10)
5/79	I	67.0	7.2	(13)	30.8	10.3	(13)	28.2	4.9	(13)	53.3	11.1	(13)
5/79	II	73.8	10.6	(6)	31.2	15.2	(6)	30.0	7.2	(6)	29.3	16.4	(6)
5/79	III	49.3	7.5	(12)	54.8	10.3	(13)	36.4	5.3	(11)	21.5	12.1	(11)
2/81	I	51.7	2.2	(37)	31.2	2.7	(37)	27.9	2.4	(37)	31.1	6.0	(37)
2/81	II	47.6	3.6	(13)	27.9*	4.6	(13)	24.8	4.1	(13)	28.5	10.1	(13)
2/81	III	51.3	4.2	(10)	42.0*	5.2	(10)	33.1	4.6	(10)	44.5	11.5	(10)
					*p = 0.02								
Last Available Data	I	53.3	2.1	(47)	30.2*	2.1	(47)	27.5	2.1	(47)	28.1	4.7	(47)
	II	55.8	3.9	(36)	31.8+	2.6	(36)	32.3	6.5	(36)	29.1	3.3	(36)
	III	48.1	3.4	(23)	47.5*,+	9.5	(23)	35.3	5.5	(22)	44.9	16.7	(22)
					*p = 0.007 +p = 0.02								
All Visits Combined[a]	I	56.0	2.1	(84)	28.2*	1.4	(84)	27.1	1.4	(84)	28.1	3.8	(83)
	II	55.1	3.5	(52)	31.0+	2.3	(50)	30.1	4.6	(52)	29.1	3.0	(49)
	III	50.7	3.0	(43)	42.9*,+	5.8	(44)	34.1	3.6	(41)	38.5	9.3	(41)
					*p = 0.001 +p = 0.01								

(continued)

TABLE 27 (continued)

Groups and Date	Exposure Group	Alkaline Phosphatase			SGPT			SGOT			Gamma GT		
		Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
Wash. D.C. Area													
1-3/79	I	48.5	4.0	(10)	29.9	5.3	(10)	24.2	5.2	(10)	42.0*	12.2	(9)
1-3/79	II	49.0	1.6	(64)	28.5	2.1	(64)	26.8	2.1	(64)	25.4	3.5	(64)
1-3/79	III	49.9	2.0	(38)	26.1	2.7	(38)	23.9	2.7	(38)	20.7*	2.7	(37)
											*p = 0.03		
5/79	I	69.0	10.5	(3)	23.3	13.3	(3)	17.7	11.0	(3)	27.0	14.7	(3)
5/79	II	51.1	4.7	(15)	39.6*	6.0	(15)	35.4	4.9	(15)	26.1	6.6	(15)
5/79	III	55.2	5.1	(13)	21.5*	6.4	(13)	24.4	5.3	(13)	31.4	7.3	(12)
					*p = 0.05								
9/79	I	46.6	5.5	(5)	27.4	9.3	(5)	25.8	6.9	(5)	43.6	19.0	(5)
9/79	II	48.1	2.7	(21)	30.1	4.6	(21)	29.0	3.4	(21)	31.6	9.3	(21)
9/79	III	44.9	2.5	(25)	24.6	4.2	(25)	24.3	3.2	(24)	25.1	8.5	(25)
2/81	I	49.5	4.1	(8)	38.9	30.7	(8)	42.5	29.1	(8)	61.0	22.1	(8)
2/81	II	51.4*	2.8	(17)	59.1	21.1	(17)	44.0	20.0	(17)	39.2	15.2	(17)
2/81	III	43.3*	2.8	(15)	93.7	22.4	(15)	101.5	21.3	(15)	47.9	16.1	(15)
		*p = 0.05											
Last	I	53.9	4.3	(23)	41.7	7.0	(22)	39.5	5.5	(23)	44.3	10.0	(22)
Available	II	48.6	1.5	(84)	37.1	5.4	(84)	32.7	3.6	(84)	27.2	3.6	(84)
Data	III	48.0	1.4	(81)	40.1	5.6	(81)	41.6	6.5	(81)	34.6	5.0	(81)
All	I	51.3	2.8	(40)	35.8	4.3	(39)	33.3	3.5	(40)	43.6*	6.7	(38)
Visits	II	49.0	1.1	(140)	35.5	3.5	(140)	32.0	2.5	(140)	29.2*	3.1	(140)
Combined[a]	III	48.3	1.2	(118)	36.7	4.0	(118)	37.6	4.7	(117)	30.1	3.6	(116)
											*p = 0.04		

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[a] Includes data from visits not listed individually because of small group sizes.

TABLE 28. COMPARISON OF ALKALINE PHOSPHATASE AND TRANSAMINASE LEVELS AMONG EXPOSURE GROUPS: COMBINED AREAS, 1979 and 1981

Date	Exposure Group	Alkaline Phosphatase Mean	Alkaline Phosphatase Std. Error	Alkaline Phosphatase (n)	SGPT Mean	SGPT Std. Error	SGPT (n)	SGOT Mean	SGOT Std. Error	SGOT (n)	Gamma GT Mean	Gamma GT Std. Error	Gamma GT (n)
1-3/79	I	51.3	3.0	(24)	25.6	3.4	(24)	24.2	3.4	(24)	25.7	7.6	(23)
1-3/79	II	49.9	1.7	(79)	29.6	1.9	(79)	26.6	1.9	(79)	27.0	4.1	(78)
1-3/79	III	51.1	2.1	(48)	26.3	2.4	(48)	25.8	2.4	(48)	28.2	5.3	(47)
5/79	I	67.4*	7.8	(16)	29.4	8.1	(16)	26.2	4.6	(16)	48.4*	12.9	(16)
5/79	II	57.6	4.3	(21)	37.2	7.1	(21)	33.9	4.0	(21)	27.0	4.6	(21)
5/79	III	52.4*	3.7	(25)	38.1	6.3	(26)	29.9	3.8	(24)	26.7*	5.3	(23)
		*p = 0.04									*p = 0.05		
9/79	I	45.2	5.0	(6)	26.0	8.4	(6)	26.0	6.2	(6)	36.8	17.1	(6)
9/79	II	48.1	2.7	(21)	30.1	4.5	(21)	29.0	3.3	(21)	31.6	9.1	(21)
9/79	III	45.4	2.4	(26)	24.7	4.0	(20)	24.3	3.0	(25)	24.8	8.2	(26)
2/81	I	51.3	1.9	(45)	32.5*	2.3	(45)	30.5*	2.4	(45)	36.4	7.2	(45)
2/81	II	49.8	2.3	(30)	45.6	13.9	(30)	35.7*	8.3	(30)	34.6	8.8	(30)
2/81	III	46.5	2.5	(25)	73.0*	15.3	(25)	74.2*,+	19.3	(25)	46.6	9.7	(25)
					*p = 0.06			*p = 0.002 +p = 0.02					
Last Available Data	I	53.5*	2.0	(70)	33.9	2.7	(69)	31.4	2.4	(70)	33.3	4.6	(69)
	II	50.8	1.6	(120)	35.5	3.8	(120)	32.6	3.2	(120)	27.8	2.7	(120)
	III	48.0*	1.3	(104)	41.8	4.8	(104)	40.3	5.3	(103)	36.8	5.3	(103)
		*p = 0.03											
All Visits Combined[a]	I	54.5*,+	1.7	(124)	30.6	1.7	(123)	29.1	1.5	(124)	33.1	3.4	(121)
	II	50.7*	1.2	(192)	34.3	2.6	(190)	31.5	2.2	(192)	29.4	2.4	(189)
	III	49.0*	1.2	(161)	38.4	3.3	(162)	36.7	3.6	(158)	32.3	3.6	(157)
		*p = 0.05 +p = 0.006											

[a] Includes data from visits not listed individually because of small group sizes.

TABLE 29. COMPARISONS OF ALBUMIN, TOTAL BILIRUBIN AND DIRECT BILIRUBIN LEVELS AMONG EXPOSURE GROUPS, 1979 AND 1981

Groups and Date	Exposure Group	Albumin Mean	Albumin Std. Error	Albumin (n)	Total Bilirubin Mean	Total Bilirubin Std. Error	Total Bilirubin (n)	Direct Bilirubin Mean	Direct Bilirubin Std. Error	Direct Bilirubin (n)
Camden-Phil. Area										
1-3/79	I	4.36	0.14	(14)	0.53	0.06	(7)	0.20	0.40	(7)
1-3/79	II	4.54	0.13	(15)	0.47	0.05	(10)	0.22	0.33	(10)
1-3/79	III	4.48	0.16	(10)	0.37	0.06	(7)	0.20	0.42	(6)
5/79	I	5.69	0.25	(13)	0.64	0.09	(9)	0.23	0.03	(9)
5/79	II	5.43	0.37	(6)	0.50	0.12	(5)	0.26	0.04	(5)
5/79	III	5.21	0.25	(13)	0.61	0.09	(8)	0.24	0.03	(8)
2/81	I	4.53*	0.83	(37)	0.28*	0.04	(37)			
2/81	II	4.58	1.41	(13)	0.25+	0.08	(12)			
2/81	III	8.72*	1.61	(10)	0.50*,+	0.09	(10)			
		*p = 0.02			*p = 0.03, +p = 0.04					
Last Available Data	I	4.64	0.58	(47)	0.34*	0.04	(45)	0.20	0.01	(23)
	II	4.74	0.66	(36)	0.38	0.06	(26)	0.23	0.03	(19)
	III	6.39	0.82	(23)	0.51*	0.07	(18)	0.22	0.02	(14)
					*p = 0.04					
All Visits Combined[a]	I	4.69	0.08	(83)	0.39	0.03	(63)	0.20	0.01	(26)
	II	4.66	0.10	(52)	0.40	0.03	(34)	0.22	0.02	(22)
	III	5.70	0.92	(44)	0.51	0.07	(27)	0.22	0.02	(16)
Wash. D.C. Area										
1-3/79	I	4.57	0.17	(10)	0.60	0.12	(8)	0.24	0.04	(7)
1-3/79	II	4.47	0.07	(64)	0.57	0.05	(42)	0.24	0.02	(39)
1-3/79	III	4.49	0.08	(38)	0.60	0.07	(27)	0.20	0.02	(25)
5/79	I	5.03	0.49	(3)	0.20*,+	0.12	(3)	0.13	0.04	(3)
5/79	II	5.30	0.22	(15)	0.56*	0.10	(7)	0.19	0.03	(7)
5/79	III	4.90	0.25	(12)	0.54+	0.07	(12)	0.22	0.02	(12)
					*,+p = 0.05					
9/79	I	4.44	0.16	(5)	0.50	0.17	(3)	0.27	0.06	(3)
9/79	II	4.68	0.08	(21)	0.51	0.08	(15)	0.25	0.03	(13)
9/79	III	4.52	0.07	(25)	0.43	0.07	(18)	0.22	0.03	(18)

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TABLE 29 (continued)

Groups and Date	Exposure Group	Albumin			Total Bilirubin			Direct Bilirubin		
		Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
Wash. D.C. Area										
2/81	I	4.34^{*}	0.07	(8)	0.45	0.07	(8)			
2/81	II	4.41^{+}	0.07	(17)	0.57^{*}	0.05	(17)			
2/81	III	$4.69^{*,+}$	0.12	(15)	0.34^{*}	0.06	(15)			
		$^{*,+}p = 0.03$			$^{*}p = 0.005$					
Last Available Data	I	$6.19^{*,+}$	0.60	(23)	0.56	0.08	(21)	0.23	0.04	(11)
	II	4.55^{*}	0.31	(84)	0.45	0.03	(66)	0.21	0.01	(47)
	III	4.48^{+}	0.32	(81)	0.41	0.03	(77)	0.22	0.02	(39)
		$^{*}p = 0.02$ $^{+}p = 0.01$								
All Visits Combined[a]	I	$5.50^{*,+}$	0.37	(40)	0.54	0.13	(29)	0.21	0.03	(14)
	II	4.59^{*}	0.20	(139)	0.50	0.03	(99)	0.23	0.01	(61)
	III	4.55^{+}	0.22	(117)	0.45	0.03	(98)	0.21	0.01	(59)
		$^{*,+}p = 0.03$								

[a] Includes data from visits not listed individually because of small group sizes.

TABLE 30. COMPARISONS OF ALBUMIN, TOTAL BILIRUBIN AND DIRECT BILIRUBIN LEVELS AMONG EXPOSURE GROUPS: COMBINED AREAS, 1979 AND 1981

		Albumin			Total Bilirubin			Direct Bilirubin		
Date	Exposure Group	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
1-3/79	I	4.45	0.11	(24)	0.57	0.08	(15)	0.22	0.03	(14)
1-3/79	II	4.48	0.06	(79)	0.55	0.04	(52)	0.23	0.02	(49)
1-3/79	III	4.49	0.07	(48)	0.55	0.05	(34)	0.20	0.02	(31)
5/79	I	5.57	0.22	(16)	0.53	0.08	(12)	0.21	0.02	(12)
5/79	II	5.34	0.19	(21)	0.53	0.08	(12)	0.22	0.02	(12)
5/79	III	5.06	0.17	(25)	0.57	0.06	(20)	0.23	0.02	(20)
2/81	I	4.50	0.60	(45)	0.31*	0.04	(45)			(0)
2/81	II	4.48	0.73	(30)	0.44*	0.05	(29)			(0)
2/81	III	6.30	0.81	(25)	0.40	0.05	(25)			(0)
					*p = 0.05					
Last Available Data	I	5.15	0.40	(70)	0.41	0.04	(66)	0.21	0.02	(34)
	II	4.61	0.31	(120)	0.43	0.04	(92)	0.22	0.01	(66)
	III	4.90	0.33	(104)		0.04	(95)	0.22	0.01	(53)
All Visits Combined[a]	I	4.95	0.33	(123)	0.44	0.05	(92)	0.20	0.01	(40)
	II	4.61	0.04	(191)	0.48	0.02	(133)	0.23	0.01	(83)
	III	4.87	0.03	(161)	0.46	0.03	(125)	0.21	0.01	(75)

[a] Includes data from visits not listed individually because of small group sizes.

Determination of Antibody Against *Histoplasma capsulatum* and *Aspergillus* spp. by Counter Immunoelectrophosis

Three hundred and eighty-nine serum samples were tested by CIE for the presence of precipitins against: (1) the H and M antigens of *Histoplasma capsulatum* and, (2) a pool of antigens derived from *A. fumigatus*, *A. flavus*, *A. carneus*, and *A. niger*. No precipitins were detected in the sera tested against any of these antigens. Positive reactions were documented concurrently with control antisera.

Hypersensitivity to *A. fumigatus*

Skin reactivity to *Aspergillus* antigens was determined on 109 participants during the first year of the study. Only five persons tested positive, three compost workers, one intermediate-exposed worker and one control. These results do not indicate any difference among exposure groups.

Determination of Antibody Against LPS and *A. fumigatus* by ELISA

The presence of antibody of the IgG class in sera obtained from the workers directed against antigens prepared from *A. fumigatus* and LPS prepared from compost obtained from the Beltsville and Camden facilities was determined by the ELISA technique (Tables 31, 32, 33). In May and December 1979 there were significant differences in the titer of IgG antibody directed against *A. fumigatus* antigens in workers from the Washington, D.C. area with compost workers having the highest levels (Table 32). However, for the Camden-Philadelphia (Table 31) and combined areas (Table 40) control and intermediate-exposed workers had the highest antibody titers.

For IgG against compost-derived LPS there were 15 significant ($p < 0.05$) comparisons and the compost workers had the highest values in each case. However in some of these cases the intermediate-exposed group had lower levels than the controls but these differences were not statistically different. There appears to be some evidence, based on these results, that compost-exposed workers have higher levels of IgG antibody against compost-derived LPS than do workers with lower or no exposure to compost. Eight of these comparisons involved the workers in each area separately. These differences were divided equally between situations where the differences were for IgG against "local" compost LPS and for IgG against LPS from compost from another area, indicating that there appeared to be either no immunity to local antigens or that there was no essential difference between LPS from the two areas.

C-Reactive Protein, C3, Hemolytic Complement (CH_{50}) and Immunoglobulin Analyses

Comparison of results for C3B, C-Reactive Protein (CRP) and CH_{50} are presented in Tables 34, 35 and 36 for the Camden-Philadelphia area, Washington, D.C. metropolitan areas and combined areas, respectively. For C3B and CRP the significant comparisons ($p < 0.05$) are inconsistent with respect to which exposure group had highest levels. However for C3B the only

TABLE 31. COMPARISONS OF ELISA-DETERMINED IGG ANTIBODY DIRECTED AGAINST A. FUMIGATUS AND AGAINST COMPOST DERIVED LIPOPOLYSACCHARIDE GROUPS: CAMDEN AND PHILADELPHIA PARTICIPANTS, 1979-1981

		IGG Against *A. fumigatus*			IGG Against Beltsville Compost			IGG Against Camden Compost		
Date	Exposure Group	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
1-3/79	I	0.821	0.124	(8)	1.129	0.143	(7)	1.018	0.087	(7)
1-3/79	II	0.566*	0.117	(9)	1.107	0.134	(8)	0.870	0.081	(8)
1-3/79	III	0.927*	0.124	(8)	1.218	0.154	(6)	0.989	0.093	(6)
		*p = 0.05								
5/79	I	0.754	0.213	(18)	1.114	0.105	(17)	1.059	0.213	(17)
5/79	II	0.823	0.273	(11)	0.978	0.136	(10)	1.130	0.277	(10)
5/79	III	1.324	0.197	(21)	1.123	0.099	(19)	1.224	0.201	(19)
7/79	I	0.884	0.119	(20)	1.215*	0.103	(19)	1.150	0.090	(19)
7/79	II	0.715	0.122	(19)	0.858*	0.103	(19)	0.948	0.090	(19)
7/79	III	0.866	0.133	(16)	1.034	0.116	(15)	0.944	0.102	(15)
					*p = 0.02					
12/79	I	1.105	0.143	(19)	0.943	0.106	(19)	0.842	0.077	(19)
12/79	II	0.792	0.180	(12)	1.020	0.133	(12)	0.798	0.097	(12)
12/79	III	0.971	0.167	(14)	1.068	0.124	(14)	0.877	0.089	(14)
9/80	I	1.157	0.165	(38)	1.375	0.062	(39)	1.516*	0.091	(39)
9/80	II	0.936	0.207	(24)	1.290	0.079	(24)	1.225*	0.116	(24)
9/80	III	1.462	0.281	(13)	1.273	0.107	(13)	1.368	0.157	(13)
								*p = 0.05		
11/80	I	1.245	0.184	(35)	1.318	0.069	(35)	1.517	0.173	(35)
11/80	II	1.965	0.243	(20)	1.392	0.092	(20)	1.249	0.229	(20)
11/80	III	1.088	0.328	(11)	1.165	0.124	(11)	1.330	0.309	(11)
2/81	I	1.141	0.237	(35)	1.269	0.065	(36)	1.286	0.053	(36)
2/81	II	0.813	0.389	(13)	1.358	0.108	(13)	1.235	0.089	(13)
2/81	III	1.886	0.443	(10)	1.149	0.123	(10)	1.422	0.101	(10)
Last	I	1.085	0.169	(50)	1.257*	0.050	(51)	1.268*	0.046	(51)
Avail-	II	0.816*	0.065	(40)	1.171	0.068	(40)	1.106*	0.058	(43)
able	III	1.363*	0.292	(24)	1.080*	0.067	(23)	1.154	0.086	(23)
		*p = 0.05			*p = 0.05			*p = 0.03		
All	I	1.077*	0.082	(173)	1.240	0.030	(172)	1.288*	0.058	(172)
Visits	II	0.829*,$^{+}$	0.039	(108)	1.166	0.046	(106)	1.097*	0.035	(106)
Com- bined	III	1.210^{+}	0.122	(93)	1.136	0.047	(88)	1.162	0.075	(88)
		*p = 0.04 +p = 0.006						*p = 0.02		

TABLE 32. COMPARISONS OF ELISA-DETERMINED IGG ANTIBODY DIRECTED AGAINST A. FUMIGATUS AND AGAINST COMPOST-DERIVED LIPOPOLYSACCHARIDE: WASHINGTON, D.C. METROPOLITAN AREA, 1979-1981

Date	Exposure Group	IGG Against A. fumigatus			IGG Against Beltsville Compost			IGG Against Camden Compost		
		Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
1-3/79	I	1.080	0.237	(10)	1.141	0.139	(10)	1.343	0.151	(10)
1-3/79	II	1.112	0.156	(23)	1.094	0.094	(22)	1.208	0.102	(22)
1-3/79	III	0.797	0.208	(13)	1.032	0.122	(13)	1.055	0.138	(12)
5/79	I	1.235*,+	0.161	(11)	1.374*	0.122	(11)	1.571	0.287	(11)
5/79	II	0.872*	0.094	(21)	1.115	0.102	(19)	1.172	0.095	(19)
5/79	III	0.662+	0.097	(9)	0.866*	0.112	(9)	1.155	0.135	(9)
		*p = 0.03, +p = 0.006			*p = 0.02					
7/79	I	1.207	0.129	(10)	1.283*	0.133	(8)	1.443	0.130	(9)
7/79	II	1.037	0.136	(9)	0.894*	0.120	(9)	1.157	0.130	(9)
7/79	III	0.938	0.118	(12)	1.074	0.086	(11)	1.141	0.124	(10)
					*p = 0.03					
9/79	I	1.214	0.231	(11)	1.214	0.143	(10)	1.264	0.117	(10)
9/79	II	1.076	0.167	(21)	1.086	0.098	(21)	1.168	0.080	(21)
9/79	III	0.891	0.256	(9)	1.005	0.150	(9)	1.186	0.123	(9)
12/79	I	1.112*	0.094	(14)	1.232	0.137	(13)	1.312	0.127	(13)
12/79	II	0.768*	0.140	(13)	1.313	0.137	(13)	1.009	0.127	(13)
12/79	III	0.849	0.086	(16)	1.010	0.120	(17)	1.013	0.111	(17)
		*p = .03								
9/80	I	1.094	0.204	(14)	1.144	0.124	(15)	1.193	0.102	(15)
9/80	II	1.195	0.221	(12)	1.340	0.103	(22)	1.185	0.084	(22)
9/80	III	1.394	0.133	(33)	1.237	0.083	(34)	1.324	0.068	(34)
11/80	I	0.997	0.222	(9)	1.150	0.160	(9)	1.164	0.124	(9)
11/80	II	1.125	0.185	(13)	1.146	0.105	(21)	1.183	0.083	(20)
11/80	III	1.390	0.126	(28)	1.371	0.089	(29)	1.368	0.069	(29)
2/81	I	0.911	0.140	(7)	1.190	0.130	(8)	1.242	0.117	(8)
2/81	II	0.983	0.112	(11)	1.133	0.089	(17)	1.102	0.080	(17)
2/81	III	1.073	0.096	(15)	1.184	0.095	(15)	1.220	0.085	(15)
Last Available	I	1.102	0.101	(25)	1.166	0.074	(24)	1.221	0.068	(25)
	II	1.024	0.089	(39)	1.116	0.055	(52)	1.093	0.046	(52)
	III	1.144	0.091	(63)	1.112	0.060	(66)	1.171	0.058	(66)
All Visits Combined	I	1.117	0.048	(86)	1.214	0.035	(84)	1.314*	0.042	(85)
	II	1.021	0.062	(123)	1.153	0.042	(144)	1.156*	0.033	(143)
	III	1.115	0.058	(134)	1.159	0.040	(133)	1.225	0.037	(135)
								*p = 0.008		

TABLE 33. COMPARISON OF ELISA-DETERMINED IGG ANTIBODY DIRECTED AGAINST *A. FUMIGATUS* AND AGAINST COMPOST-DERIVED LIPOPOLYSACCHARIDE: COMBINED AREAS, 1979-1981

		IGG Against *A. fumigatus*			IGG Against Beltsville Compost			IGG Against Camden Compost		
Date	Exposure Group	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
1-3/79	I	0.965	0.154	(18)	1.136	0.101	(17)	1.209	0.104	(17)
1-3/79	II	0.958	0.116	(32)	1.097	0.076	(30)	1.118	0.078	(30)
1-3/79	III	0.846	0.143	(21)	1.091	0.095	(19)	1.033	0.101	(18)
5/79	I	0.936	0.140	(29)	1.216	0.084	(28)	1.260	0.145	(28)
5/79	II	0.855	0.133	(32)	1.068	0.082	(29)	1.158	0.143	(29)
5/79	III	1.126	0.138	(30)	1.040	0.084	(28)	1.202	0.145	(28)
7/79	I	0.992	0.091	(30)	1.235*	0.092	(27)	1.244*,+	0.082	(28)
7/79	II	0.818	0.095	(28)	0.870*	0.066	(28)	1.015*	0.068	(28)
7/79	III	0.897	0.095	(28)	1.051	0.076	(26)	1.023+	0.082	(25)
					*p = 0.001			*p= 0.04, +p = 0.05		
9/79	I	1.214	0.231	(11)	1.214	0.143	(10)	1.264	0.117	(10)
9/79	II	1.076	0.167	(21)	1.086	0.098	(21)	1.168	0.080	(21)
9/79	III	0.891	0.256	(9)	1.005	0.150	(9)	1.186	0.123	(9)
12/79	I	1.108*	0.112	(33)	1.060	0.086	(32)	1.033	0.075	(32)
12/79	II	0.779*	0.100	(25)	1.172	0.097	(25)	0.907	0.085	(25)
12/79	III	0.908	0.064	(29)	1.036	0.087	(31)	0.952	0.076	(31)
		*p = 0.02								
9/80	I	1.140	0.119	(52)	1.311	0.045	(54)	1.426*	0.087	(54)
9/80	II	1.022*	0.087	(36)	1.314	0.077	(46)	1.206*	0.050	(46)
9/80	III	1.413*	0.170	(46)	1.247	0.064	(47)	1.336	0.062	(47)
			*p = 0.05					*p = 0.03		
11/80	I	1.194	0.139	(44)	1.284	0.068	(44)	1.445	0.118	(44)
11/80	II	1.028	0.161	(33)	1.266	0.070	(41)	1.216	0.124	(40)
11/80	III	1.305	0.148	(39)	1.314	0.071	(40)	1.358	0.124	(40)
2/81	I	1.102	0.178	(42)	1.255	0.057	(44)	1.278	0.049	(44)
2/81	II	0.891	0.235	(24)	1.230	0.069	(30)	1.160	0.059	(30)
2/81	III	1.398	0.230	(25)	1.170	0.076	(25)	1.301	0.065	(25)
Last Available	I	1.091	0.117	(75)	1.235*	0.042	(75)	1.253*	0.038	(76)
	II	0.919*	0.056	(79)	1.140	0.043	(92)	1.099*	0.036	(92)
	III	1.205*	0.104	(87)	1.104*	0.048	(89)	1.166	0.048	(89)
		*p = 0.04			*p = 0.04			*p = 0.01		
All Visits Combined	I	1.090*	0.057	(259)	1.231*	0.023	(256)	1.297*	0.043	(257)
	II	0.931*,$^+$	0.038	(231)	1.159	0.031	(250)	1.131*	0.024	(249)
	III	1.154$^+$	0.060	(227)	1.150*	0.030	(225)	1.200	0.037	(223)
		*p = 0.03 +p = 0.004			*p = 0.05			*p = 0.001		

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TABLE 34. COMPARISONS OF CONCENTRATIONS OF C3B, C-REACTIVE PROTEIN AND CH$_{50}$ AMONG EXPOSURE GROUPS: CAMDEN-PHILADELPHIA AREA, 1979-1981

		C3B			C-Reactive Protein			CH$_{50}$		
Date	Exposure Group	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
1-3/79	I	46.39	3.83	(14)	0.407	0.188	(14)	110.8	7.2	(14)
1-3/79	II	42.59	3.70	(15)	0.468	0.181	(15)	117.0	7.2	(14)
1-3/79	III	36.89	4.53	(10)	0.547	0.222	(10)	125.6	8.5	(10)
5/79	I	35.10	4.03	(25)	0.291	0.119	(24)	101.3	5.0	(15)
5/79	II	46.78	4.75	(18)	0.580	0.130	(20)	104.2	5.1	(14)
5/79	III	44.05	4.20	(23)	0.310	0.119	(24)	114.9	6.1	(10)
7/79	I	35.06	2.09	(29)	0.399	0.078	(28)	113.2	3.5	(18)
7/79	II	32.11*	2.46	(21)	0.350	0.092	(20)	107.9	5.0	(9)
7/79	III	40.27*	2.58	(19)	0.211	0.095	(19)	101.0	5.7	(7)
		*p = 0.03								
9/79	I			(0)			(0)			(0)
9/79	II			(0)			(0)			(0)
9/79	III			(0)			(0)			(0)
12/79	I	36.73	2.73	(28)	0.449	0.090	(30)	110.5	4.9	(16)
12/79	II	35.68	3.87	(14)	0.371	0.131	(14)	106.5	6.9	(8)
12/79	III	43.46	3.62	(16)	0.281	0.127	(15)	104.7	8.0	(6)
9/80	I	47.71	2.19	(40)	0.263	0.053	(40)			(0)
9/80	II	44.58	2.95	(22)	0.157	0.069	(23)			(0)
9/80	III	48.11	3.84	(13)	0.108	0.092	(13)			(0)
11/80	I	40.09	1.34	(35)	0.367	0.106	(36)			(0)
11/80	II	38.10	1.77	(20)	0.536	0.142	(20)			(0)
11/80	III	35.64	2.39	(11)	0.209	0.192	(11)			(0)
2/81	I	40.96	1.64	(37)	0.338	0.072	(37)			(0)
2/81	II	42.93	2.77	(13)	0.354	0.121	(13)			(0)
2/81	III	41.56	3.15	(10)	0.070	0.138	(10)			(0)
Last	I	40.23	1.22	(55)	0.338	0.061	(55)	112.8	4.0	(21)
Avail-	II	40.52	2.33	(44)	0.381*	0.079	(44)	107.3	5.2	(17)
able	III	40.88	3.22	(24)	0.143*	0.074	(24)	114.8	5.8	(11)
					*p = 0.05					
All	I	40.38	0.79	(208)	0.352	0.030	(209)	109.1	2.3	(63)
Visits	II	40.29	0.52	(123)	0.398*	0.057	(125)	109.3	3.1	(45)
Combined	III	41.92	1.52	(102)	0.250*	0.045	(103)	113.3	4.5	(33)
					*p = 0.03					

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TABLE 35. COMPARISONS OF CONCENTRATIONS OF C3B, C-REACTIVE PROTEIN AND CH_{50} AMONG EXPOSURE GROUPS: WASHINGTON, D.C. METROPOLITAN AREA, 1979-1981

		C3B			C-Reactive Protein			CH_{50}		
Date	Exposure Group	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
1-3/79	I	44.01	4.58	(13)	0.337	0.196	(12)	114.8	5.6	(12)
1-3/79	II	43.73	2.23	(55)	0.293	0.093	(53)	117.1	3.6	(30)
1-3/79	III	41.74	2.72	(37)	0.450	0.113	(36)	109.6	3.6	(29)
5/79	I	41.59	4.88	(13)	0.335	0.192	(13)	124.5*	6.9	(13)
5/79	II	46.33	2.78	(40)	0.265	0.109	(40)	109.8	5.0	(27)
5/79	III	48.54	2.97	(35)	0.505	0.119	(34)	102.9*	4.8	(25)
								*p = 0.01		
7/79	I	37.18	3.55	(9)	0.397	0.149	(10)	121.6*,+	4.4	(14)
7/79	II	46.92*	4.30	(20)	0.227	0.103	(21)	106.8*	6.3	(17)
7/79	III	34.77*	1.63	(29)	0.410	0.089	(28)	102.4+	3.1	(29)
		*p = 0.003						*p = 0.04, +p = 0.004		
9/79	I	36.59*	2.17	(14)	0.265	0.110	(14)	121.9	5.1	(16)
9/79	II	45.24*,+	2.86	(34)	0.273	0.073	(32)	112.5	4.2	(24)
9/79	III	38.49+	1.57	(37)	0.302	0.070	(34)	113.2	3.8	(29)
		*p = 0.04, +p = 0.03								
12/79	I	39.62	3.44	(15)	0.349	0.133	(15)	124.3*	5.4	(16)
12/79	II	42.95	1.88	(50)	0.318	0.074	(48)	116.9	5.4	(21)
12/79	III	39.17	2.22	(36)	0.178	0.085	(37)	107.4*	5.1	(27)
								*p = 0.04		
9/80	I	56.79*,+	5.85	(14)	0.214	0.119	(14)			(0)
9/80	II	45.59*	1.90	(22)	0.168	0.095	(22)			(0)
9/80	III	47.03+	2.54	(36)	0.323	0.075	(35)			(0)
		*p = 0.04, +p = 0.05								
11/80	I	47.89*,+	3.35	(9)	0.378	0.137	(9)			(0)
11/80	II	39.98*	1.40	(22)	0.145	0.088	(22)			(0)
11/80	III	40.57+	1.79	(29)	0.255	0.077	(29)			(0)
		*,+p = 0.03								
2/81	I	63.64*,+	7.30	(8)	0.475	0.163	(8)			(0)
2/81	II	42.52*	2.43	(17)	0.124	0.112	(17)			(0)
2/81	III	39.59+	2.45	(15)	0.373	0.119	(15)			(0)
		*p = 0.004, +p = 0.0001								

(continued)

TABLE 35 (continued)

Date	Exposure Group	C3B Mean	C3B Std. Error	C3B (n)	C-Reactive Protein Mean	C-Reactive Protein Std. Error	C-Reactive Protein (n)	CH_{50} Mean	CH_{50} Std. Error	CH_{50} (n)
Last Available	I	50.75*	3.23	(26)	0.237	0.065	(27)	120.6*	4.8	(22)
	II	44.41	1.51	(81)	0.251	0.052	(80)	114.1	3.9	(34)
	III	40.67*	1.61	(86)	0.342	0.069	(86)	108.5*	3.8	(42)
		*p = 0.002						*p = 0.04		
All Visits Combined	I	45.15*	1.63	(95)	0.332	0.051	(95)	121.7*,$^{+}$	2.4	(71)
	II	44.18*,$^{+}$	0.93	(260)	0.250*	0.028	(255)	113.0*,§	2.2	(119)
	III	41.53+	0.90	(254)	0.347*	0.040	(248)	107.2$^{+\S}$	1.8	(139)
		*,$^{+}$p = 0.04			*p = .04			*p = .009 +p = .0001 §p = .04		

TABLE 36. COMPARISONS OF CONCENTRATIONS OF C3B, C-REACTIVE PROTEIN AND CH_{50} AMONG EXPOSURE GROUPS: COMBINED AREAS, 1979-1981

		C3B			C-Reactive Protein			CH_{50}		
Date	Exposure Group	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
1-3/79	I	45.24	3.05	(27)	0.375	0.133	(26)	112.6	4.4	(26)
1-3/79	II	43.48	1.90	(70)	0.331	0.082	(68)	117.0	3.4	(44)
1-3/79	III	40.71	2.31	(47)	0.471	0.100	(46)	113.7	3.6	(39)
5/79	I	37.32*,+	2.02	(38)	0.307	0.107	(37)	112.1	4.5	(28)
5/79	II	46.47+	2.70	(58)	0.370	0.084	(60)	107.9	3.7	(41)
5/79	III	46.76*	2.62	(58)	0.425	0.085	(58)	106.3	4.0	(35)
		*,+p = 0.02								
7/79	I	35.56	2.12	(38)	0.398	0.072	(38)	116.9*,+	2.3	(32)
7/79	II	39.33	2.04	(41)	0.287	0.069	(41)	107.2*	4.5	(26)
7/79	III	36.95	1.88	(48)	0.330	0.064	(47)	102.1+	3.0	(36)
								*p=0.05, +p=0.001		
9/79	I	36.59*	2.17	(14)	0.265	0.110	(14)	121.9	5.1	(16)
9/79	II	45.24*,+	2.86	(34)	0.273	0.073	(32)	112.5	4.2	(24)
9/79	III	38.49+	1.57	(37)	0.302	0.070	(34)	113.2	3.8	(29)
		*p = 0.04, +p = 0.03								
12/79	I	37.74	2.11	(43)	0.416*	0.083	(45)	117.4	4.1	(32)
12/79	II	41.36	1.73	(64)	0.330	0.070	(62)	114.0	4.3	(29)
12/79	III	40.49	1.91	(52)	0.208*	0.051	(52)	106.9	4.1	(33)
					*p = 0.04					
9/80	I	50.06	1.99	(54)	0.250	0.053	(54)			(0)
9/80	II	45.09	2.20	(45)	0.162	0.058	(44)			(0)
9/80	III	47.32	2.09	(49)	0.265	0.056	(48)			(0)
11/80	I	41.68	1.29	(44)	0.369	0.082	(45)			(0)
11/80	II	39.09	1.32	(42)	0.331	0.084	(42)			(0)
11/80	III	39.22	1.35	(40)	0.243	0.087	(40)			(0)
2/81	I	45.00	1.85	(45)	0.362	0.067	(45)			(0)
2/81	II	42.70	2.26	(30)	0.223	0.082	(30)			(0)
2/81	III	40.38	2.48	(25)	0.252	0.090	(25)			(0)
Last Available	I	43.61	1.42	(81)	0.305	0.046	(82)	116.8	3.2	(43)
	II	43.04	1.28	(125)	0.297	0.044	(124)	111.8	3.1	(51)
	III	40.71	1.43	(110)	0.298	0.057	(110)	108.5	3.2	(53)
All Visits Combined	I	41.88	0.75	(303)	0.346	0.027)	(304)	115.8*	1.7	(134)
	II	42.93	0.80	(383)	0.299	0.027	(380)	112.0	1.8	(164)
	III	41.64	0.77	(356)	0.319	0.031	(350)	108.4*	1.7	(172)
								*p = 0.004		

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difference at $p \leq 0.001$ were situations where the compost group had highest levels: Washington, D.C. February 1981 ($p = 0.0001$). For the last available data comparison, which involves all participants, the compost group had the highest levels and the control group the lowest ($p = 0.002$). For CH_{50} in the Washington, D.C. area and for both areas combined there were seven comparisons where $p \leq 0.05$ and in each the compost workers had highest levels and controls, lowest. These results suggest that exposure to compost in the work environment may lead to a low-grade inflammatory response with elevated concentrations of acute phase reactants such as C3 and hemolytic complement. Furthermore, these responses may be seasonal with maximal inflammation occurring during periods of the year which are hot and dry; these conditions result in greater amounts of dust in the air at compost facilities.

Comparison of IgA, IgE, IgG and IgM concentrations among the exposure groups are presented in Table 37 (Camden-Philadelphia area), Table 38 (Washington, D.C. metropolitan area) and Table 39 (combined areas). For all the situations where statistically significant differences occurred either the intermediate-exposed or control groups had highest levels.

Legionella pneumophila Antibody

Legionella pneumophila antibody titers were measured in paired sera from 83 compost and intermediate-exposed workers and 38 controls. In addition, single specimens were analyzed from 5 compost workers and 9 intermediate-exposed workers. Six men had four-fold increases in antibody, including four workers and two controls. Two of the workers were from the high exposure group and two from the partially exposed groups. Six additional men had antibody titers $\geq$ 1:128 to at least one of the four serogroups, but did not have a significant increase in antibody. These six included three compost workers and three controls. These results indicate that there appears to be no increased risk of *Legionella pneumophila* infection in the compost workers studied. It is interesting that the overall infection rate as indicated by rising antibody titers was 4.9%. This is much higher than the infection rate noted in the previous study of wastewater workers (0.8% per year) (1).

A summary of the 4-fold and greater titer level rises by area and exposure group (Table 40) reveals no apparent difference among exposure groups. However, on an area basis there are more titer level rises in the Camden-Philadelphia area than in the Washington, D.C.-Beltsville, MD area ($p = 0.08$). A tabulation of the highest titer level to any of the serotypes for all workers tested, using the second specimen results for workers tested twice, is presented in Table 41. The Camden-Philadelphia area has a higher percent of workers with titer levels $\geq$ 128 than the Washington, D.C.-Beltsville, MD area, 13 percent and 4 percent, respectively.

Cultures of Anterior Nares and Throat Swabs

During December 1980 a group of 33 study participants (9 compost workers, 12 intermediate-exposed workers and 12 controls) from Washington, D.C.-Beltsville, MD who participated in the Friday and Monday pre- and post-shift pulmonary function testing also had anterior nares and throat swabs collected from them. Nares and throat swabs from Friday after shift and from both Monday

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TABLE 37. COMPARISON OF IGA, IGE, IGG AND IGM CONCENTRATIONS AMONG EXPOSURE GROUPS: CAMDEN-PHILADELPHIA AREA, 1979

		IGA			IGE			IGG			IGM		
Date	Exposure Group	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
1-3/79	I	304.4*	33.2	(14)	47.5	35.3	(2)	534.9	66.0	(13)	204.3	27.8	(12)
1-3/79	II	211.6*,+	32.1	(15)	51.1	18.9	(7)	478.7	61.4	(15)	179.3*	24.8	(15)
1-3/79	III	321.4+	39.3	(10)	43.5	25.0	(4)	410.1	75.2	(10)	274.6*	30.4	(10)
		*p = 0.05, +p = 0.04									*p = 0.02		
5/79	I	229.8	22.6	(24)			(1)	494.1	55.8	(24)	178.7	15.9	(24)
5/79	II	234.1	26.1	(18)	294.4	179.6	(5)	471.1	61.1	(20)	161.1	17.8	(19)
5/79	III	282.2	22.6	(24)			(1)	461.8	55.8	(24)	184.3	16.2	(23)
7/79	I	224.5	15.6	(28)	141.8	125.4	(6)	488.4	59.4	(27)	174.7	13.5	(28)
7/79	II	181.5*	18.0	(21)	416.3	177.3	(3)	419.3	69.0	(20)	179.5	15.2	(22)
7/79	III	260.3*	18.9	(19)	53.0	217.2	(2)	443.9	69.0	(20)	190.0	16.0	(20)
		*p = 0.004											
9/79	I			(0)			(0)			(0)			(0)
9/79	II			(1)			(0)			(0)			(0)
9/79	III			(0)			(0)			(0)			(1)
12/79	I	236.3	18.1	(29)	102.8	32.8	(13)	352.9*	58.4	(22)	185.5	12.9	(30)
12/79	II	181.4*	26.1	(14)	111.2	32.8	(13)	542.7*	73.2	(14)	176.9	19.6	(13)
12/79	III	286.4*	24.4	(16)	36.7	44.7	(7)	483.1	68.4	(16)	182.3	17.6	(16)
		*p = 0.005						*p = 0.05					
Last Avail-able	I	249.3*	19.4	(41)	105.7	27.7	(22)	433.0	44.2	(35)	174.1	10.5	(42)
	II	198.1*,+	14.5	(32)	158.7	52.0	(27)	480.4	51.1	(32)	178.1	12.7	(33)
	III	294.2+	22.5	(27)	66.9	26.6	(14)	492.3	54.0	(27)	192.2	15.6	(27)
		*p = .05 +p = 0.001											
All Visits Combined	I	241.2*,+	10.9	(95)	105.7	27.7	(22)	462.3	29.6	(86)	182.9	8.0	(94)
	II	201.7*,§	11.1	(69)	161.6	50.2	(28)	472.3	33.1	(69)	173.9	8.5	(69)
	III	282.8+,§	13.0	(69)	66.9	26.6	(14)	454.2	33.9	(70)	197.8	10.2	(70)
		*p = 0.02 +p = 0.01 §p = 0.0001											

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TABLE 38. COMPARISON OF IGA, IGE, IGG AND IGM CONCENTRATIONS AMONG EXPOSURE GROUPS: WASHINGTON, D.C. METROPOLITAN AREA, 1979

Date	Exposure Group	IGA			IGE			IGG			IGM		
		Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
1-3/79	I	261.9	30.1	(13)			(0)	467.4	77.8	(13)	190.7	26.3	(12)
1-3/79	II	239.4	15.0	(52)	122.7*	52.8	(7)	460.7	37.2	(57)	218.0	12.6	(52)
1-3/79	III	268.9	17.6	(38)	88.0*	54.0	(2)	444.8	45.5	(38)	189.0	15.2	(36)
					*p = 0.04								
5/79	I	259.3	33.0	(13)			(0)	551.7	78.6	(13)	172.9	26.4	(13)
5/79	II	241.5	18.8	(40)			(0)	476.3	44.8	(40)	208.6	15.2	(39)
5/79	III	265.4	20.1	(35)	54.5	9.5	(2)	415.8	46.6	(37)	196.5	16.1	(35)
7/79	I	275.4	48.0	(10)			(0)		91.5	(10)	209.3	28.8	(10)
7/79	II	255.6	33.1	(21)	33.0		(1)	412.5	63.1	(21)	200.5	20.9	(19)
7/79	III	299.8	28.7	(28)	72.5		(2)	456.8	53.7	(29)	153.9	17.2	(28)
9/79	I	264.4	31.9	(14)	25.0	51.3	(2)	504.1	73.0	(14)	181.3	24.1	(13)
9/79	II	227.9	20.5	(34)	46.5	51.3	(2)	463.2	46.8	(34)	182.2	14.9	(34)
9/79	III	262.4	19.9	(36)	88.4	25.6	(8)	445.9	44.9	(37)	182.1	14.5	(36)
12/79	I	274.3*	29.5	(15)	91.4	66.3	(11)	350.2*	48.3	(15)	184.1	23.1	(15)
12/79	II	186.7*,+	12.2	(49)	159.0	46.9	(22)	493.2*,+	35.7	(50)	201.8	12.8	(49)
12/79	III	285.9*	23.0	(35)	171.6	42.3	(27)	340.3*	38.0	(38)	198.4	14.7	(37)
		*p = 0.008, +p = 0.0001						*p = 0.04, +p = 0.004					
Last Available	I	256.6	24.8	(21)	81.2	22.1	(13)	393.0	46.5	(21)	195.7	17.9	(19)
	II	203.8*	11.4	(70)	140.1	37.2	(32)	478.1*	32.2	(70)	205.4	9.8	(70)
	III	281.3*	19.7	(53)	140.8	31.3	(41)	360.1*	32.9	(55)	196.3	14.1	(54)
		*p = 0.0004						*p = 0.01					
All Visits Combined	I	266.9*	13.8	(65)	81.2	22.1	(13)	482.2	32.5	(65)	186.5	10.6	(63)
	II	226.4*,+	7.0	(196)	140.1	37.2	(32)	467.3	19.1	(202)	204.0*	6.3	(193)
	III	275.3+	10.4	(172)	140.8	31.3	(41)	418.8	20.5	(179)	185.4*	7.3	(172)
		*p = 0.02 +p = 0.0001									*p = 0.05		

TABLE 39. COMPARISON OF IGA, IGE, IGG AND IGM CONCENTRATIONS AMONG EXPOSURE GROUPS: COMBINED AREAS, 1979

		IGA			IGE			IGG			IGM		
Date	Exposure Group	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
1-3/79	I	284.0*	23.5	(27)	47.5	66.6	(2)	501.2	52.6	(26)	197.5	19.3	(24)
1-3/79	II	233.1*,+	12.2	(67)	86.9	25.2	(14)	464.5	31.6	(72)	209.3	11.5	(67)
1-3/79	III	279.8+	16.3	(48)	58.3	38.5	(6)	437.6	38.7	(48)	207.6	13.9	(46)
		*p = 0.05, +p = 0.03											
5/79	I	240.2	18.9	(37)	42.0	347.5	(1)	514.3	45.6	(37)	176.7	14.5	(37)
5/79	II	239.2	15.1	(58)	294.4	155.4	(5)	474.6	35.8	(60)	193.1	11.6	(58)
5/79	III	272.3	15.0	(59)	169.7	200.6	(3)	433.9	35.5	(61)	191.7	11.6	(58)
7/79	I	237.9	16.2	(38)	141.8	114.9	(6)	512.7	48.8	(37)	183.8	13.2	(38)
7/79	II	218.5*	15.4	(42)	320.5	140.8	(4)	415.8	46.4	(41)	189.2	12.7	(41)
7/79	III	283.9*	22.0	(47)	62.8	140.8	(4)	451.5	42.4	(49)	168.9	11.7	(48)
		*p = 0.01											
9/79	I	264.4	31.8	(14)	25.0	51.3	(2)	504.1	73.0	(14)	181.3	24.0	(13)
9/79	II	226.6	20.1	(35)	46.5	51.3	(2)	463.2	46.8	(34)	182.2	14.8	(34)
9/79	III	262.4	19.8	(36)	88.4	25.6	(8)	445.9	44.9	(37)	181.1	14.2	(37)
12/79	I	249.3*	15.6	(44)	97.6	39.1	(24)	351.8*	36.7	(37)	185.0	12.3	(45)
12/79	II	185.5*,+	11.1	(63)	141.2	32.4	(35)	504.0*,+	33.0	(64)	196.6	10.5	(62)
12/79	III	286.1+	17.4	(51)	143.9	32.8	(34)	382.6+	34.4	(54)	193.5	11.3	(53)
		*p = 0.002, +p = 0.0001						*p = 0.004, +p = 0.01					
Last Avail-able	I	251.8*	15.3	(62)	96.6	19.1	(35)	418.0	32.5	(56)	180.9	9.1	(61)
	II	202.0*,+	9.0	(102)	148.6	30.9	(50)	478.8*	27.2	(102)	196.6	7.9	(103)
	III	285.6+	15.0	(80)	122.0	24.6	(55)	403.6*	29.0	(82)	194.9	10.7	(81)
		*p = 0.007 +p = 0.0001						*p = 0.04					
All Visits Combined	I	251.6*,+	8.6	(160)	96.6	19.1	(35)	470.9	21.9	(151)	184.4	6.4	(157)
	II	220.0*,§	5.9	(265	150.1	30.4	(60)	468.5	16.5	(271)	196.1	5.2	(262)
	III	277.5+,§	8.6	(241)	122.0	24.6	(55)	428.7	17.6	(249)	189.0	6.0	(242)
		*p = 0.006 +p = 0.03 §p = 0.0001											

TABLE 40. 4-FOLD AND GREATER TITER LEVEL INCREASES TO LEGIONELLA PNEUMOPHILA ANTIBODY

	Number of Workers							
	Compost		Intermediate-Exposed		Control		Total	
Area	No. Tested	No. Titer Level Rises	No. Tested	No. Titer Level Rises	No. Tested	No. Titer Level Rises	No. Tested	No. Titer Level Rises
Camden, NJ-Philadelphia, PA	35	2	15	2	16	2	66	6
Washington, D.C.-Beltsville, MD	9	0	24	0	22	0	55	0
							$x^2 = 3.14$	$p = 0.08$
Totals	44	2	39	2	38	2	121	6

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TABLE 41. COMPARISON OF HIGHEST TITER LEVELS TO LEGIONELLA PNEUMOPHILA IN WORKERS BY AREA AND EXPOSURE

Area	Exposure	Total No. Workers	Number (Percent) of Workers with Specified Titer Levels <64	64	≥128
Camden, NJ-Philadelphia, PA					
	Compost Worker	35	27(77)	5(14)	3(9)
	Intermediate-exposed	16	10(63)	3(19)	3(19)
	Control	17	11(65)	3(18)	3(18)
Area Totals		68	48(71)	11(16)	9(13)
Washington, D.C.-Beltsville, MD					
	Compost Worker	13	12(92)	1(8)	0(0)
	Intermediate-exposed	32	25(78)	5(16)	2(6)
	Control	22	17(72)	4(18)	1(5)
Area Totals		67	54(81)	10(15)	3(4)
Combined Areas					
	Compost Worker	48	39(81)	6(13)	3(6)
	Intermediate-exposed	48	35(73)	8(17)	5(10)
	Control	39	28(72)	7(18)	4(10)
Overall		135	102(76)	21(16)	12(9)

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sessions were cultured for *A. fumigatus* and other thermophilic fungi. All nares and throat swabs from control workers and all throat swabs from the other two groups were negative. The results for individual workers from the anterior nares for the compost workers and the intermediate-exposed groups are shown in Table 42. The specimen most frequently found positive was the Monday end-of-shift specimens from the Blue Plains compost workers (5 of 6). All workers were seen at the job site prior to sampling which could account for the three positive Monday pre-shift specimens; however it is possible that the two day absence from compost work could have been sufficient for the upper respiratory tract of some of the workers to be cleansed of the viable fungal units while it was not adequate for some of the other worker's systems to do so. A summary of all data by exposure group is presented in Table 43.

Comparison among exposure groups of average number of *A. fumigatus* colonies in combined nose and throat swabs for the 1979 study results are presented in Table 44. The consistent differences between the groups with compost workers having highest levels, except for the all negative data for the first visit, support the exposure category designations. Even though viable *A. fumigatus* spores are ubiquitous, their concentration in the vicinity of compost sites is sufficiently elevated above background to result in a significantly higher degree of "colonization" among compost-exposed workers. Biopsies would be required to determine if the fungi were actually multiplying in the upper respiratory tract.

Length of Compost Exposure-Serologic and Culture Data Correlations

An effort was made to determine if the serologic test results reported in Tables 22 through 39 were related to length of compost exposure in years. Results from testing of the last available serum specimen for each compost worker (Group I) were compared with length of compost exposure by regression analyses. Significance levels for all comparisons of regression equation slopes are presented in Table 45. For all comparisons with $p < 0.10$, estimates and standard errors for the regression equation slopes and intercepts are presented in Table 46. Of interest here are the positive correlations of IgG against *A. fumigatus* and Camden-compost-LPS and with IgE (Camden-Philadelphia area only). For the last correlation, the regression equation suggests that one year of exposure to compost would more than double serum IgE concentrations. The intercept of the regression equation was not significantly different from zero ($p = 0.74$).

Airborne Fungal Counts

Data from the air sampling analyses for *A. fumigatus* and other thermophilic fungi were tested for statistically significant differences as follows.

In the first comparison, differences in air concentrations in total *A. fumigatus*, respirable *A. fumigatus*, total "other thermophilic," and respirable "other thermophilic" were tested among the four compost plant sampling site classifications: Nearby "Active" Compost Plant Sampling Sites (within 30 meters upwind or 100 meters downwind of any compost operation); Nearby "Inactive" Outdoor Compost Plant Sampling Sites, Distant Upwind "Active"

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TABLE 42. RESULTS OF CULTURES FOR *A. FUMIGATUS* AND OTHER THERMOPHILIC FUNGI OF PRE AND POST SHIFT ANTERIOR NARES FROM COMPOST AND INTERMEDIATE-EXPOSED WORKERS AT THE BLUE PLAINS (D.C.) AND BELTSVILLE (MD) SITES

	Friday Post-shift	Monday Pre-shift (number of colonies)	Monday Post-shift
Compost workers			
Blue Plains	0	0	5
	1	0	7
		0	1
	0	0	1
	0	0	0
	0	1	2
Beltsville	0	2	0
	2	0	0
	0		
	0		0
Intermediate-exposed			
Blue Plains	0	0	
	0	0	0
	0	0	0
	0	0	0
	0	0	
	0		0
Beltsville	0	0	0
		2	0
		0	
	0	0	0
	0		0
	0	0	

(blank indicates no specimen)

All nares from controls and all throat swabs from all groups were negative.

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TABLE 43. RESULTS OF CULTURES FOR A. FUMIGATUS OF ANTERIOR NARES FROM WORKERS PARTICIPATING IN PRE AND POST SHIFT PULMONARY FUNCTION TESTING

(a) Positive/Negative

	Friday Post-shift		Monday Pre-shift		Monday Post-shift*	
Group	Number	Number positive	Number	Number positive	Number	Number positive
1	9	2	8	2	9	5
2	10	0	10	1	8	0
3	12	0	11	0	8	0

*Groups 1 & 2 and Groups 1 & 3 different by Fisher's Exact Test, p = 0.04.

(b) Number of Colonies

	Friday Post-shift		Monday Pre-shift		Monday Post-shift	
Group	Number Samples	Total # colonies	Number Samples	Total # colonies	Number samples	Total # colonies
1	9	3	8	3	9	16
2	10	0	10	2	8	0
3	12	0	11	0	8	0

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TABLE 44. COMPARISONS AMONG EXPOSURE GROUPS OF AVERAGE NUMBER OF A. FUMIGATUS COLONIES IN COMBINED NOSE AND THROAT CULTURES, 1979

		Camden-Phila Area			Wash., D.C. Area			Combined Area		
Date	Exposure Group	Mean	Std. Error	(n)	Mean	Std. Error	(n)	Mean	Std. Error	(n)
1-3/79	I	0.00		(10)	0.00		(9)	0.00		(19)
1-3/79	II	0.00		(14)	0.00		(67)	0.00		(81)
1-3/79	III	0.00		(9)	0.00		(31)	0.00		(40)
5/79	I	0.64*	0.29	(25)	3.85*,+	1.00	(13)	1.74*,+	0.46	(38)
5/79	II	0.20	0.12	(20)	0.26*	0.16	(39)	0.24*	0.11	(59)
5/79	III	0.00*	0.00	(25)	0.03+	0.03	(39)	0.02+	0.02	(64)
		*p = 0.02			*,+p = 0.0001			*,+p = 0.0001		
7/79	I	1.67*,+	0.48	(30)	2.57*,+	0.71	(14)	1.95*,+	0.40	(44)
7/79	II	0.23*	0.13	(26)	0.04*	0.04	(23)	0.14*	0.07	(49)
7/79	III	0.00+	0.00	(23)	0.00+	0.00	(30)	0.00+	0.00	(53)
		*p = 0.0005 +p = 0.002			*,+p = 0.0001			*,+p = 0.0001		
9/79	I	1.74*,+	0.53	(27)	1.06*,+	0.55	(17)	1.48*,+	0.39	(44)
9/79	II	0.00*	0.00	(20)	0.00*	0.00	(35)	0.00*	0.00	(50)
9/79	III	0.00+	0.00	(19)	0.03+	0.03	(40)	0.02+	0.02	(50)
		*,+p = 0.002			*,+p = 0.0004			*,+p = 0.0001		
12/79	I	0.47*,+	0.03	(34)	0.81*,+	0.43	(16)	0.58*,+	0.09	(50)
12/79	II	0.00*	0.00	(19)	0.00*	0.00	(63)	0.00*	0.00	(82)
12/79	III	0.00+	0.00	(15)	0.00+	0.00	(37)	0.00+	0.00	(52)
		*p = 0.01 +p = 0.02			*,+p = 0.0001			*,+p = 0.0001		
Last Available Data	I	0.61*,+	0.18	(44)	1.26*,+	0.46	(23)	0.84*,+	0.20	(67)
	II	0.06*	0.04	(36)	0.01*	0.01	(93)	0.02*	0.01	(129)
	III	0.00*	0.00	(22)	0.01+	0.01	(67)	0.01+	0.01	(95)
		*,+p = 0.002			*,+p = 0.0001			*,+p = 0.0001		
All Visits Combined	I	1.02*,+	0.18	(126)	1.70*,+	0.32	(69)	1.26*,+	0.17	(195)
	II	0.10*	0.04	(99)	0.05*	0.03	(227)	0.06*	0.02	(326)
	III	0.00+	0.00	(91)	0.01+	0.01	(177)	0.01+	0.01	(268)
		*,+p = 0.0001			*,+p = 0.0001			*,+p = 0.0001		

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TABLE 45. SIGNIFICANCE LEVELS FOR COMPARISONS OF LENGTH OF COMPOST EXPOSURE FOR EXPOSURE GROUP ONE WORKERS VS LAST AVAILABLE SEROLOGIC DATA

Variable	Combined Areas	Camden-Philadelphia Area	Washington, D.C. Area
White cell count, per cu mm	.7553	.7215	.7276
Eosinophiles, %	.9751	.2672	.1428
Eosinophile count, per cu mm	.5883	.3524	.1612
IGG against *A. fumigatus*	.9563	.3448	.0916
IGG against Beltsville compost	.5044	.3681	.9918
IGG against Camden compost	.1710	.8978	.0598
IGG	.0176	.1504	.0468
IGA	.4462	.0526	.7623
IGM	.3788	.8129	.2316
IGE	.3611	.0543	.9277
C3B	.0619	.8611	.0906
C-Reactive protein	.6880	.9610	.4844
CH 50	.5765	.7338	.4076
Alkaline phosphatase	.1051	.9945	.0883
SGPT	.5230	.5906	.6314
SGOT	.6296	.4561	.3343
SGGT	.6259	.7945	.6336
Albumin	.5971	.0906	.6622
Total Bilirubin	.4205	.0132	.9658
Direct Bilirubin	.7471	.9123	.6709
BUN	.5773	.0544	.2579
Creatinine	.6445	.1362	.7313
A. fumigatus colonies	.5231	.5599	.2998

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TABLE 46. RESULTS OF REGRESSION ANALYSIS OF LAST AVAILABLE SEROLOGIC DATA AND LENGTH OF COMPOST EXPOSURE IN YEARS ($p \leq 0.10$ FOR AT LEAST ONE OF THE COMPARISONS)

			Slope*			Intercept*	
Variable	Worker Group	p	Estimate	Std. Error	p	Estimate	Std. Error
IgG against *A. fumigatus*	Wash., D.C. area	0.09	0.095	0.054	0.0001	0.925	0.141
IgG against Camden compost	Wash., D.C. area	0.06	0.072	0.036	0.0001	1.082	0.095
IgG	Combined areas	0.02	-57.9	23.7	0.0001	493.7	43.9
IgG	Wash., D.C. area	0.05	-50.4	23.7	0.0001	473.8	57.3
IgA	Camden-Phila. area	0.05	-44.7	22.3	0.0001	294.6	29.4
IgE	Camden-Phila. area	0.05	81.9	40.1	0.74	17.0	50.5
C3B	Combined areas	0.06	2.04	1.08	0.0001	39.91	2.40
C3B	Wash., D.C. area	0.09	3.09	1.75	0.0001	44.94	4.52
Albumin	Camden-Phila. area	0.09	-.13	0.08	0.0001	4.87	0.16
Total Bilirubin	Camden-Phila. area	0.01	-0.09	0.03	0.0001	0.49	0.07
BUN	Camden-Phila.	0.54	-1.17	0.59	0.0001	17.8	1.2
Alkaline phosphatase	Wash., D.C. area	0.09	-3.99	2.23	0.0001	61.8	6.01

*From regression equation: Variable = (slope) (# Yrs. composting) + Intercept

Compost Sites (more than 30 meters upwind of compost site); Distant Upwind "Inactive" Outdoor Compost Site. The median concentrations and significance of difference by rank test are presented in Table 47. Differences were found for both total and respirable *A. fumigatus* ($p < 0.05$) with highest levels found downwind of "nearby" and upwind of "distant" active compost operations.

In the next comparison air concentrations for the above four fungal groupings at Nearby Compost Sites were tested for difference among the three classifications of operational level; Active; Intermittent-Activity; Inactive. The median concentrations and significance of difference by rank test are presented in Table 48. Although the differences between sites are about the same as in Table 47, no significant differences were detected, probably because of the small sample size.

In the third comparison air concentrations for the four fungal groupings at Distant Compost Site locations were tested for differences among the three classifications of operational level: Active; Intermittent-Activity; Inactive. The median concentrations and significance of difference by rank test are presented in Table 49. Again, no significant differences were found, probably due to small sample size.

In the next comparison air concentrations for the fungal groupings were compared among eight classifications of type of sampling site: 1. Nearby Compost Sites; 2. Distant Compost Sites; 3. Indoor Compost Waste Sites; 4. Indoor Compost Area No-Waste Site; 5. Outdoor Sewage Treatment Site; 6. Indoor Sewage Treatment Waste Site; 7. Indoor Sewage Treatment No-Waste Site; 8. Water Service Site. The median concentrations and significances of differences by rank test are presented in Table 50. Significant differences were found for both total and respirable *A. fumigatus* with highest levels detected at indoor compost sites.

Spearman rank correlation coefficients and significance levels, for comparisons among all of the data for the fungal groupings (Table 51) revealed position correlation ($p < .001$) for all comparisons. Highest correlation coefficients were for comparison between respirable and total levels for the same fungal type: *A. fumigatus* (0.97), and other thermophilic, (0.87). When such comparisons were made for data collected for nearby compost sites, at sites distant from composting operations and at outdoor sewage treatment sites significant correlations were evident only when total and respirable counts for the same fungal type were compared (Tables 52, 53 and 54).

Air concentrations for four fungal groupings were divided into the following four precedent rainfall categories: 1. Less than 0.15" in the preceding 1 day, 2 days, and 7 days; 2. Less than 0.15" in the preceding 1 day and 2 days and more than 0.14" in the preceding 7 days; 3. Less than 0.15" in the preceding day, and more than 0.14" in the preceding 2 days and 7 days; 4. More than 0.14" in the preceding 1 day, 2 days and 7 days. The median concentrations for and significance of difference by rank test among these categories are presented in Table 55. Significant differences were revealed for both total and respirable *A. fumigatus* ($p < 0.01$) with concentrations generally highest for category 3 indicating that airborne fungal con-

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TABLE 47. MEDIAN AIR CONCENTRATIONS BY FUNGAL GROUP AND COMPOST SITE CLASSIFICATION

	(Colony forming units/cubic meter)								Significance of Difference
	Nearby Active		Nearby Inactive		Distant Up-wind Active		Distant Up-wind Inactive		
Total *A fumigatus*	750	(n=14)	100	(n=23)	10	(n=2)	20	(n=2)	0.0358
Respirable *A. fumigatus*	590	(n=14)	60	(n=23)	650	(n=2)	10	(n=6)	0.0343
Total Other	100	(n=13)	30	(n=23)	60	(n=2)	20	(n=6)	0.4564
Respirable Other	100	(n=13)	10	(n=23)	680	(n=2)	10	(n=6)	0.7014

TABLE 48. MEDIAN AIR CONCENTRATIONS BY FUNGAL GROUP AND BY LEVEL OF ACTIVITY AT NEARBY COMPOST SITE

	(Colony forming units/cubic meter)			Significance of Difference
	Active	Intermittent	Inactive	
Total *A. fumigatus*	750 (n=14)	70 (n=2)	100 (n=23)	0.1319
Respirable *A. fumigatus*	590 (n=14)	60 (n=2)	60 (n=23)	0.0871
Total Other	100 (n=13)	400 (n=3)	40 (n=23)	0.1142
Respirable Other	100 (n=13)	200 (n=3)	10 (n=23)	0.1481

TABLE 49. MEDIAN AIR CONCENTRATIONS BY FUNGAL GROUP AND BY LEVEL OF ACTIVITY AT DISTANT COMPOST SITE

	(Colony forming units/cubic meter) Active	Intermittent	Inactive	Significance of Difference
Total *A. fumigatus*	680 (n=2)	- (n=0)	20 (n=6)	0.4047
Respirable *A. fumigatus*	650 (n=2)	- (n=0)	10 (n=6)	0.2433
Total Other	60 (n=2)	- (n=0)	20 (n=6)	0.8676
Respirable Other	10 (n=2)	- (n=0)	20 (n=6)	0.6171

TABLE 50. MEDIAN AIR CONCENTRATIONS BY FUNGAL GROUP AND CLASS OF COMPOST SITE*

	(Colony forming units/cubic meter) Site Class								Significance of Difference
	1	2	3	4	5	6	7	8	
Total *A. fumigatus*	750 n=14	10 n=26	1870 n=2	0 n=5	0 n=28	0 n=3	20 n=1	0 n=5	0.0012
Respirable *A. fumigatus*	590 n=14	0 n=26	1340 n=2	0 n=5	0 n=28	0 n=3	10 n=1	0 n=5	0.0015
Total Other	100 n=13	10 n=26	270 n=2	10 n=5	0 n=28	0 n=3	0 n=1	10 n=5	0.0951
Respirable Other	100 n=13	10 n=26	230 n=2	10 n=5	0 n=28	0 n=3	0 n=1	0 n=5	0.3900

*1 = nearby compost site, 2 = distant compost site, 3 = indoor compost waste site, 4 = indoor no compost waste site, 5 = outdoor sewage treatment site, 6 = indoor sewage treatment site, 7 = indoor non-waste site, and 8 = waste service site.

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TABLE 51. RANK CORRELATION COEFFICIENTS BY FUNGAL GROUP FOR ALL DATA

	Total *A. fumigatus*	Respirable *A. fumigatus*	Total Other
Respirable *A. fumigatus*	0.9702 p = 0.0001 n=84		
Total Other	0.3927 p = 0.0003 n=82	0.3636 p = 0.0008 n=82	
Respirable Other	0.3992 p = 0.0002 n=82	0.3595 p = 0.0009 n=82	0.8667 p = 0.0001 n=83

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TABLE 52. RANK CORRELATION COEFFICIENTS BY FUNGAL GROUP FOR NEARBY COMPOST SITES

	Total *A. fumigatus*	Respirable *A. fumigatus*	Total Other
Respirable *A fumigatus*	0.9736 p = 0.0001 n=14		
Total Other	0.4162 p = 0.1783 n=12	0.3669 p = 0.2408 n=12	
Respirable Other	0.4140 p = 0.1809 n=12	0.3632 p = 0.2459 n=12	0.9560 p = 0.0001 n=13

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TABLE 53. RANK CORRELATION COEFFICIENTS BY FUNGAL GROUP FOR DISTANT COMPOST SITES

	Total *A. fumigatus*	Respirable *A. fumigatus*	Total Other
Respirable *A. fumigatus*	0.9093 p = 0.0001 n=26		
Total Other	0.2214 p = 0.2771 n=26	0.1854 p = 0.3645 n=26	
Respirable Other	0.2967 p = 0.1411 n=26	0.2342 p = 0.2495 n=26	0.8518 p = 0.0001 n=26

TABLE 54. RANK CORRELATION COEFFICIENTS BY FUNGAL GROUP FOR OUTDOOR SEWAGE TREATMENT SITES

	Total *A. fumigatus*	Respirable *A. fumigatus*	Total Other
Respirable *A. fumigatus*	0.8895 p = 0.0001 n=28		
Total Other	0.0449 p = 0.8206 n=28	0.0189 p = 0.9238 n=28	
Respirable Other	0.0242 p = 0.9026 n=28	0.0117 p = 0.9531 n=28	0.9959 p = 0.0001 n=28

TABLE 55. MEDIAN AIR CONCENTRATIONS BY FUNGAL GROUP BY RAINFALL CATEGORY

	1	2	3	4	Significance of Difference
Total *A. fumigatus*	30 (n=39)	-	50 (n=18)	0 (n=14)	0.0064
Respirable *A. fumigatus*	10 (n=39)	-	50 (n=18)	0 (n=14)	0.0095
Total Other	70 (n=40)	-	70 (n=18)	0 (n=14)	0.1187
Respirable Other	40 (n=40)	-	30 (n=18)	0 (n=14)	0.2600

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centrations one day after rain appear to be as high as concentrations prior to rainfall and for both of these times are higher than in the 24 hours after rainfall.

Air concentrations in four fungal groupings divided into the following three windspeed categories: 1. 0-2 mph; 2. 3-9 mph; 3. 10-25 mph were tested for significant difference by rank test, using data from all sampling sites (Table 56). Concentrations tended to increase with increase in windspeed but differences were only close to significance for respirable concentrations of other thermophilic fungi.

Air concentrations for the fungal groupings were divided into the following three qualitative wind categories that were noted by the person performing the air monitoring for fungi: 1. Variable; 2. Light and Calm; 3. Steady, breezy, gusty. The median concentrations for and significance of difference by rank test among these categories are presented in Table 57 and revealed differences only for other thermophilic fungi and concentrations were highest for the "steady, breezy, gusty" wind category. There is no direct relationship between analyses presented in Tables 56 and 57, because the wind observation in Table 57 are subjective, relate to changes in wind speed and were not made for all samples.

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Aflatoxin in Compost

A 700 g sample of compost was negative (<1 ppb) for aflatoxin. Based on this result additional testing for aflatoxin was not performed. Airborne dust in a building where refuse derived fuel (RDF) was being prepared were reported to contain 15 ppb of aflatoxin B1 (21). Fungal concentrations CFU/m^3, had previously been detected at 53,000, 22,000 and 13,000 for A. fumigatus, A. flavus, and A. niger, respectively (40). The concentration of A. flavus was much higher than in the present study where it was rarely detected. Our result of <1 ppb is consistent with the RDF study.

Endotoxin in Compost

A method for determining the concentration for endotoxin, quantitative chemical marker, β-hydroxymyristic acid (BHM), was developed as an alternative to the widely used Limulus amoebocyte lysate (LAL) biological assay (Appendix H). A bulk sample of compost was found to contain 10-20 μg/g of BHM and thus a mininum of 10-20 μg/g of endotoxin. This concentration is at the low end of the range of the endotoxin concentration of 14 bulk samples of compost from Sweden, analyzed by the LAL method, 10-200 μg/g (29).

SUMMARY

A summary of significant findings of the study appear in Table 58.

Cultures of the throat and anterior nares of workers at compost sites were frequently positive for Aspergillus fumigatus; similar cultures obtained from workers in the intermediate-exposure group and controls were

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TABLE 56. MEDIAN AIR CONCENTRATIONS BY FUNGAL GROUP BY WINDSPEED

	0-2 mph	3-9 mph	10-15 mph	Significance of Difference
Total *A. fumigatus*	0 (n=60)	20 (n=129)	20 (n=58)	0.0982
Respirable *A. fumigatus*	0 (n=60)	10 (n=129)	20 (n=58)	0.0621
Total Other	20 (n=61)	30 (n=127)	90 (n=58)	0.1984
Respirable Other	10 (n=61)	10 (n=128)	50 (n=58)	0.0534

TABLE 57. MEDIAN AIR CONCENTRATIONS BY FUNGAL GROUP BY TYPE OF WIND

	Variable	Light and Calm	Steady, Breezy, Gusty	Significance of Difference
Total *A. fumigatus*	20 (n=30)	0 (n=35)	20 (n=78)	0.4824
Respirable *A. fumigatus*	10 (n=30)	0 (n=35)	10 (n=78)	0.6248
Total Other	0 (n=30)	50 (n=36)	60 (n=78)	0.0084
Respirable Other	0 (n=30)	10 (n=36)	30 (n=78)	0.0223

TABLE 58. SUMMARY OF FINDINGS

Excess of nasal, ear and skin abnormalities (by physical exams) in compost and intermediate-exposed workers

Symptoms of burning eyes and skin irritation higher in compost and intermediate-exposed workers

Fungal colonies greater in cultures from compost workers

Legionella infections higher in Philadelphia-Camden area

Evidence of higher white blood cell counts, eosinophile count and hemolytic complement in compost workers

Higher antibody levels to compost-endotoxin in compost workers generally negative for *A. fumigatus*. These results suggest that fungal spores in the environment at the compost site may have resulted in the colonization of the upper respiratory tracts of the workers at the compost sites studied.

The finding, from physical examinations, of higher rates of abnormal skin, ear and nose conditions among compost and intermediate-exposed workers, suggests that exposure to compost may be having an adverse impact on the health of the workers so exposed. In one of the cities, Camden, the intermediate-exposed workers were working in very close proximity to the compost workers, a fact which may account in part for an increased number of disorders in category II workers. One worker was found to have an ear infection with *A. niger* and an abnormal chest X-ray possibly related to exposure to dust at the compost site. The suggestions of an increased number of illness symptoms of burning eyes and skin irritation is consistent with the physical examination findings. At a compost plant not included in the physical examination, 5 of 15 workers reported skin rashes in early 1982. Three were reported to have been related to fungal infections.

The lowered FVC among compost workers on Monday morning compared to Friday afternoon is difficult to explain since weekend absence from a pulmonary irritant would be more likely to have the opposite effect (44).

Specific antibody directed against the H and M antigens of *H. capsulatum* or a pool of antigens prepared from *A. fumigatus*, *A. flavus*, *A. carneus*, and *A. niger* was not detected in the sera obtained from any of the study participants. These results suggest that serologically-detectable infections caused by these fungi were uncommon among the workers studied, despite the exposure of compost workers to high numbers of fungal spores at the compost sites.

The increased levels of hemolytic complement, white blood cells and eosinophile count observed among compost workers in some of the comparisons are suggestive of a low-grade inflammatory response.

The effects observed in this study may be due to the nature of the compost process itself and therefore may not be related specifically to the use of wastewater sludge in the composting operations. However, they do justify a continuation of health studies of workers engaged in the composting of waste materials. The fact that sludge composting has been practiced for a relatively short period of time adds to the need for additional study.

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SECTION 5

SEROLOGIC SURVEY

During our previous sero-epidemiologic study of the health effects of wastewater exposure of workers in Cincinnati, OH, Chicago, IL and Memphis, TN (1,3), we were generally unable to demonstrate an increase in viral infections as indicated by viral isolations, or by antibody titers as measured mostly with neutralization tests of selected sera. Several questions were raised during the study, and recommendations were proposed to resolve them (Appendix A). Some of the work under this section of the Cooperative Agreement was designed specifically to address some of them and therefore to make the former study more complete. A serum bank was established during the previous study, thus allowing us to perform additional serologic studies in several areas. The areas considered included hepatitis A seroconversions, neutralizing antibody in consecutive serum specimens, evidence of Legionnaires' Disease, testing for antibodies to Norwalk agent, rotaviruses and to the alga prototheca. The cooperative nature of this program provided flexibility in determining the exact nature of the testing to be performed.

The previous wastewater worker health study included the collection of sera every quarter (three months) from study participants. The sera was analyzed extensively for antibodies to viruses and bacteria. Also included in the study protocol was continuous collection of self-reported illness data, quarterly collection of throat and rectal swabs for the isolation of viruses and bacteria, and air and wastewater monitoring. The major portion of the study took place between July 1975 and December 1978 with only a few newly hired sewer maintenance workers in Cincinnati being recruited during the prior three months. When the study was initiated, the wastewater-exposed population chosen for study was sewer maintenance workers in Cincinnati with highway maintenance workers serving as the control. The study was expanded in July 1976 to determine the potential occupational health effects of exposure to activated sludge plant aerosols (1,3) and two additional exposed population groups were added: (1) 50 men at the Cincinnati Mill Creek Sewage Treatment Plant which was in the process of being expanded from primary wastewater treatment to include the activated sludge process, and (2) a total of 100 men newly employed at activated sludge treatment plants. The latter group was recruited from Cincinnati, OH; Chicago, IL; and Memphis, TN. As additional comparison groups, water treatment plant workers were selected in Chicago, and in Memphis, workers engaged in maintenance and repair work at a gas and electric public utility. Chicago workers began joining the study during July 1976 and those in Memphis in July 1977. Volunteer recruitment was completed before the start of the last year of the study. The total number of volunteers recruited in the study was 524 (Table 59) although not all workers remained in the study the entire period.

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Table 59. NUMBER OF VOLUNTEERS RECRUITED INTO STUDY

Group	Cincinnati	Chicago	Memphis	Total
Inexperienced activated sludge	44	56	50	150
Experienced activated sludge	54	40	17	111
Inexperienced sewer maintenance	13	0	0	13
Experienced sewer maintenance	65	0	0	65
Controls	80	50	55	185
	256	146	122	524

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Hepatitis A

Hepatitis A virus (HAV) infection was a major concern because of reports suggesting the possible transmission by wastewater (46,47,48). Unfortunately, when the previous study was initiated, the techniques for measuring HAV antibody were not developed. During the course of the study two different radioimmunoassays (RIA) for anti-HAV became available. A prevalence survey for anti-HAV was conducted in 1977, using sera from workers in two study cities, Cincinnati and Chicago. A second prevalence survey was done in 1978, using sera from all three study areas, which included Memphis. The first survey used a solid-phase, double-antibody RIA; and the second survey, a competitive RIA. By analysis of co-variance, with age and race as two of the co-variables, there was no evidence of an increased prevalence of anti-HAV in the workers exposed to wastewater (Table 60). However, these populations, including the controls, have a high prevalence of anti-HAV. It is possible that the acquisition of antibody in inexperienced workers after employment was greater than in the experienced workers or controls. We attempted to evaluate this question indirectly by comparing the results of the two prevalence surveys (Table 61). Although this suggested that there was no increase in HAV infections, the conclusion was only tentative because it was based on the results of two different antibody assays. Also, the inexperienced workers in Memphis and many of the inexperienced workers from Chicago and Cincinnati only had anti-HAV measured once during the previous study and thus seroconversions could not be detected in their sera.

In the present study, the initial sera from all workers was evaluated using a competitive RIA to measure anti-HAV. Thus the population at risk (those with no serum antibody) at the beginning of the study was defined. The last sera from these workers was then tested for anti-HAV, allowing the determination of the exact frequency of seroconversions in the various study groups.

Enterovirus Neutralizing Antibody

During the previous study, two large serologic surveys were performed using serum from selected time periods (quarters). Neutralizing antibody to 25 viruses was measured in the initial survey and to 15 viruses in the final survey. Sera was selected from at least two quarters in a study period to provide an indication of the levels of antibody in the various study groups and the frequency of seroconversions or rising antibody titers. It was recognized that antibody might rise and fall in the interval between the selected test periods, but testing the sera for every quarter was not feasible. With data available at the conclusion of the previous study on the prevalence and levels of antibody, and the viruses which were present in the study areas (Table 62), a plan was developed to test a series of specimens collected in consecutive quarters for a few selected viruses. Quarterly serum specimens from experienced workers and matched controls were tested for antibodies to some of the viruses which were prevalent in the specific study area (Cincinnati, Chicago and Memphis).

Serial testing of specimens collected over a particular 12-month period was conducted for enteroviruses which were either identified in worker specimens at the mid-point of that period (Strategy A) or for which statistically significant

TABLE 60. PREVALENCE OF HEPATITIS A ANTIBODY (INCLUDES RESULTS FROM 1977 and 1978 SURVEYS IN PREVIOUS STUDY)

Worker Group	# of Workers	Number with Hepatitis A Antibody	Percent
Inexperienced Sewer Maintenance	12	7	58.3
Experienced Sewer Maintenance	60	40	66.7
Inexperienced Sewage Treatment	140	42	30.0
Experienced Sewage Treatment	108	50	46.3
Controls	177	102	57.6

TABLE 61. SEROCONVERSION TO HEPATITIS A COMBINING DATA FOR BOTH SURVEYS

Worker Group	# at Risk	# Sero-conversions	Percent
Sewage-exposed	63	11	17.5
Non-exposed	18	4	22.2

TABLE 62. ENTEROVIRUSES RECOVERED DURING THE PREVIOUS STUDY

Viruses	Wastewater Monitoring*	Study Participants**
Polio	1-3	1,3
Coxsackie	A15, B1, 3-5	A13, B2, 4, 5
Echo	1-4, 6, 7, 9, 13, 18, 33	3, 9, 31, 29

*Virus isolated from concentrates of a total of 38 24-hour composite wastewater samples collected from wastewater treatment plants in Cincinnati, Chicago and Memphis.

**Viruses isolated from throat and rectal swabs collected every 3 months from study participants.

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differences were detected between specimens collected in that 12-month period (Strategy B). The serial testing was an attempt to determine if differences between groups were missed in the previous study because of testing only a portion of the specimens collected. In addition it would help determine if the differences previously detected can be confirmed by detecting other differences during the same overall time period. For example, on a hypothetical basis, if Group A and Group B had different titer levels in specimens collected in July 1976, then the importance of that difference would be increased if the group with the higher levels also showed more titer level increases in the period prior to July 1976 than did the Group B workers.

The specific testing conducted is indicated in Table 63.

Legionella Pneumophila

In the final year of the previous study, information was available which indicated that *L. pneumophila* was an aquatic organism that may be distributed widely in our environment. It was suggested that wastewater workers should be surveyed for antibodies to this organism. A prevalence survey was conducted using an indirect immunofluorescent assay for antibodies to serotype 1. The survey showed no difference in the prevalence of antibody between sewage-exposed and non-exposed workers, although antibody was slightly more prevalent in the sewer maintenance workers.

There were two problems with this survey - the population at risk (the susceptibles) at the beginning of the study was not defined and only one serotype was tested. To be sure that there are no differences in the study groups, all initial sera were screened for antibody. Then the last serum from all susceptibles was tested. In those who developed antibody during the study period, serial serum specimens were tested for antibody to determine when seroconversion occurred. Serum from workers in a recent study of the health effects of the treatment and disposal of municipal wastewater and sludge in Muskegon, MI (2,49) was also tested. Antibody to additional serotypes of *L. pneumophila* which were available from the Center for Disease Control were also included in the survey.

Rotavirus and Norwalk Virus Study

One of the intriguing observations in the original study was the increase in gastroenteritis in inexperienced workers. This increase occurred in the spring quarter and did not correspond to the enterovirus season. Since rotavirus infections peak in the winter, it is possible that this was a cause of gastroenteritis. Rotaviruses were not included in the previous study because suitable laboratory techniques had not been developed for epidemiologic surveys. Such techniques are now available.

Serum from workers who developed gastroenteritis, workers who did not develop gastroenteritis, and from matched controls, were tested for antibodies to rotaviruses using a micro ELISA assay. We used an indirect sandwich technique with serologically related simian agent, SA-11 virus, as the antigen. This was grown in primary monkey kidney cells and extracted by treatment with

TABLE 63. ENTEROVIRUS TESTING*

Virus	City	Time Period
Strategy A: (isolations mid-point of time period)		
Echovirus 3	Cincinnati	1/77 to 1/78 (Quarters 8-12)
Coxsackievirus B2	Cincinnati	1/76 to 1/77 (Quarters 4-8)
Coxsackievirus B5	Cincinnati	10/77 to 10/78 (Quarters 11-15)
Poliovirus 1	Chicago	10/76 to 4/77 (Quarters 7-9)
Poliovirus 3	Chicago	10/76 to 4/77 (Quarters 7-9)
Stragegy B: (statistical significant titer level changes over time period)		
Echovirus 6	Cincinnati	1/76 to 1/77 (Quarters 4-8)
Echovirus 6	Chicago	1/77 to 1/78 (Quarters 8-12)

*Where a full 12-month period was used, only participants for whom at least 4 of the 5 specimens available was used unless the number of workers remaining was too small; in that case a minimum of 3 specimens was used.

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fluorocarbon. SA-11 virus has been shown to be an effective substitute for human rotavirus in serologic surveys. Because water-borne outbreaks of acute gastroenteritis have been associated with the Norwalk agent virus (50), these same sera were tested by a radioimmunoassay for Norwalk agent (2,51) in the laboratory of Dr. Blacklow at the University of Massachusetts under U.S. EPA Cooperative Agreement No. CR 810803010 to the University of Massachusetts.

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Prototheca Antibody

Prototheca are alga that have been found in waste stabilization ponds and sewage treatment plants (52). A summary of 15 human cases of histologically-proven protothecosis, presented in Appendix I (53), revealed several associated with wet environments, one of which was termed "sewage exposure." The latter case involved infection of ragged laceration of an elbow. Although the wound was inflicted as a result of an accident occurring off the job, the infection was thought to be related to the soaking of the dressing with wastewater two days later during the cleaning of a septic tank. A test for prototheca antibody has been developed by Drs. Raymond Zeiss and John Phair of Northwestern University (54,55). A preliminary testing of 15 sera, equally selected from experienced sewer maintenance, and sewage treatment and highway maintenance workers in Cincinnati, revealed a statistical difference between the groups with the sewage treatment plant workers having the highest levels (Table 64). Based on these results a decision was made in collaboration with the EPA Project Officer to have an additional 160 sera tested by this method. The sera were collected from workers in all three cities.

RESULTS

Hepatitis A

Testing for antibody to Hepatitis A antibody (anti-HAV) was completed for all participants in the Cincinnati-Chicago-Memphis wastewater worker health study according to the following protocol. Workers with serum available from at least two different collection periods were chosen for testing. The specimen collected earliest in time from such workers was then analyzed. If the initial result was negative then the latest available specimen was analyzed to determine if a seroconversion had occurred. A total of 487 workers were tested. Of the 249 for whom the initial serum was negative the last available specimen was positive for one experienced wastewater treatment plant worker and one highway maintenance worker, both in Cincinnati (Table 65). Through our routine health monitoring, both workers had reported experiencing hepatitis at a time consistent with the time period in which the seroconversion occurred. Data relating to age, race, income, and number of children were available for 446 of the workers tested for anti-HAV. An economic index was computed from the expression: Economic Index = I/(N + 1) where N is the number of children and I is the income level category. The data for both age and economic index were divided into approximately equal parts by taking ages less than 40 into the lower age group and taking economic index scores less than 2 into the lower socio-economic group.

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Associations between the worker groups and hepatitis were computed by multivariate X^2 analysis (56,57) where age, race, economic index, location and

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TABLE 64. RESULTS OF RADIOIMMUNOASSAY FOR ALGAL ANTIBODIES

Sewage Treatment	92,652
	159,042
	91,977
	157,726
	153,734
Sewer Maintenance	28,694
	157,242
	61,916
	105,212
	13,876
Highway Maintenance	20,950
	87,838
	70,516
	22,624
	8,492
Pooled Control	46,290

p = .021 by Mann-Whitney ranking test

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TABLE 65. RESULTS OF HEPATITIS A TESTING BY CITY AND WORK GROUP

		Number of Workers	
City	Work Group	Initial Serum Positive	Initial Serum Negative
Cincinnati	Inexperienced Sewage Exposed	21	28
	Experienced Sewer Maintenance	41	20
	Experienced Sewage Treatment	23	30
	Highway Maintenance	53	19
	Total	138	97
Chicago	Inexperienced Sewage Treatment	20	29
	Experienced Sewage Treatment	19	20
	Water Treatment	29	19
	Total	68	68
Memphis	Inexperienced Sewage Treatment	7	38
	Exposed Sewage Treatment*	5	15
	Light, Gas & Water	20	31
	Total	32	84
Overall Total		238	249

*Experienced, laboratory and female workers.

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experience group were included as covariables. The experience groups used were inexperienced wastewater workers, experienced wastewater workers, and controls. Associations between the covariables and hepatitis test results were examined for each location separately and for all cities combined. Demographic data for the 446 workers, by location and Hepatitis A results are presented in Table 66. The subtables of data divided according to two variables at a time are shown in Tables 67, 68, 69 and 70, for Cincinnati, Chicago, Memphis and all cities combined, respectively. When the data was adjusted for age, race, and economic index, Hepatitis A antibody results were not related to wastewater exposures for workers in any city separately or for workers in all cities combined. However, statistically significant associations were detected between and among a number of variables (Table 71 and 72). Of particular interest are the associations between anti-HAV and the co-variables race and economic index. In Cincinnati and Memphis, and for all three cities combined significantly more blacks had anti-HAV than whites ($p < 0.0001$). Economic index level was inversely associated with anti-HAV in Memphis ($p = 0.03$) and marginally associated for all three cities combined ($p = 0.07$). For all cities combined there was a three-way association between anti-HAV, race and age ($p = 0.05$) and for anti-HAV, economic index and age ($p = 0.02$). For the latter three there was also an association in Cincinnati ($p = 0.04$). As has been found elsewhere (58, 59) presence of anti-HAV was positively associated with age, in each city separately and for all cities combined ($p \leq 0.001$). For the experienced wastewater workers, presence of anti-HAV was not associated with length of exposure (Table 71).

In the initial report for the 3-city wastewater worker health study (1, pp. 111 and 114) an evaluation of anti-HAV data obtained from the Center for Disease Control (CDC) in 1977 and that from our laboratory in 1979 indicated the possibility of 15 seroconversions. The most recent and most extensive analyses by us revealed that only two of the 15 apparent seroconversions can be verified. Pairs of sera from all 15 individuals were subsequently sent to CDC in 1981 and the results confirmed our findings in all cases. Results of the 1977 CDC analyses were expressed as a P/N ratio where P was the counts per minute test result from the sample and N was the average counts per minute value of sera known to be negative. The discrepancies were traced to false negatives by CDC in 1977 in 11 cases: P/N ratios initially reported as ranging from 1.3 to 2.1 and coded negative but later testing at the University of Cincinnati (U.C.) found them to be positive. The other two cases were positive: the sera were initially reported to have P/N equal to 2.2 and later were found to be negative in testing at U.C.

Enterovirus Neutralizing Antibody

Six viruses were selected for additional study of antibody changes during a total of seven different time periods as outlined in Table 63. A summary of the tests performed and the worker groups and time periods involved is presented in Table 73. These data were analyzed both for 4-fold or more increases and for actual titer levels. Adjustments for differences in age and race were incorporated into the analyses by use of the multi-variate X^2 method, which included adjustment for small frequencies. Age was categorized into 2 groups, depending upon the year of birth being before 1939 or not. A total of 22 confirmed 4-fold or greater titer level rises were observed (Table 74).

TABLE 66. DEMOGRAPHIC CHARACTERISTICS OF PERSONS TESTED FOR HEPATITIS A ANTIBODY

Location	Hep.	Econ.*	Race	Age		Total
				<40 Yrs.	≥ 40 yrs.	
Cincinnati	Negative	1	Black	19	8	27
			White	16	5	21
			Total	35	13	48
		2	Black	9	2	11
			White	25	4	29
			Total	34	6	40
	Positive	1	Black	30	32	62
			White	7	9	16
			Total	37	41	78
		2	Black	10	20	30
			White	3	13	16
			Total	13	33	46
Chicago	Negative	1	Black	2	1	3
			White	9	9	18
			Total	11	10	21
		2	Black	2	6	8
			White	19	16	35
			Total	21	22	43
	Positive	1	Black	6	5	11
			White	4	11	15
			Total	10	16	26
		2	Black	1	7	8
			White	4	27	31
			Total	5	34	39
Memphis	Negative	1	Black	2	0	2
			White	26	1	27
			Total	28	1	29
		2	Black	7	1	8
			White	30	9	39
			Total	37	10	47
	Positive	1	Black	8	4	12
			White	3	0	3
			Total	11	4	15
		2	Black	3	4	7
			White	0	7	7
			Total	3	11	14

*Economic 1 = (Income/Number of children + 1) < 2
2 = (Income/Number of children + 1) ≥ 2

TABLE 67. HEPATITIS A RESULTS FOR ALL EXPOSURE GROUPS IN CINCINNATI

Race	Age		Total
	< 40 Yrs.	≥ 40 Yrs.	
Black	68	62	130
White	51	31	82
Total	119	93	212

Exposure	Race		Total
	Black	White	
Inexp.	12	27	39
Exp.	75	39	114
Control	43	16	59
Total	130	82	212

Economic*	Age		Total
	< 40 Yrs.	≥ 40 Yrs.	
1	72	54	126
2	47	39	86
Total	119	93	212

Hepatitis	Race		Total
	Black	White	
Negative	38	50	88
Positive	92	32	124
Total	130	82	212

Exposure	Age		Total
	< 40 Yrs.	≥ 40 Yrs.	
Inexp.	32	7	39
Exp.	64	50	114
Control	23	36	59
Total	119	93	212

Exposure	Economic*		Total
	1	2	
Inexp.	21	18	39
Exp.	71	43	114
Control	34	25	59
Total	126	86	212

Hepatitis	Age		Total
	< 40 Yrs.	≥ 40 Yrs.	
Negative	69	19	88
Positive	50	74	124
Total	119	93	212

Hepatitis	Economic*		Total
	1	2	
Negative	48	40	88
Positive	78	46	124
Total	126	86	212

Economic*	Race		Total
	Black	White	
1	89	37	126
2	41	45	86
Total	130	82	212

Hepatitis	Exposure			Total
	Inexp.	Exp.	Control	
Negative	23	50	15	88
Positive	16	64	44	124
Total	39	114	59	212

Association of Exp. and Hep. (not adjusted).
$X^2_2 = 10.12$, $p = 0.006$

Association of Exp. and Hep. (adjusted for Age, Race, Soc.).
$X^2_2 = 2.35$, $p = 0.31$

*Economic Index 1 = (Income/Number of children + 1) < 2
2 = (Income/Number of children + 1) ≥ 2

Inexp. = Inexperienced Wastewater Exposed
Exp. - Experienced Wastewater Exposed

TABLE 68. HEPATITIS A RESULTS FOR ALL EXPOSURE GROUPS IN CHICAGO

Race	Age < 40 Yrs.	Age ≥ 40 Yrs.	Total
Black	11	19	30
White	36	63	99
Total	47	82	129

Exposure	Race Black	Race White	Total
Inexp.	10	38	48
Exp.	4	34	38
Control	16	27	43
Total	30	99	129

Economic*	Age <40 Yrs.	Age ≥ 40 Yrs.	Total
1	21	26	47
2	26	56	82
Total	47	82	129

Hepatitis	Race Black	Race White	Total
Negative	11	53	64
Positive	19	46	65
Total	30	99	129

Exposure	Age <40 Yrs.	Age ≥ 40 Yrs.	Total
Inexp.	28	20	48
Exp.	5	33	38
Control	14	29	43
Total	47	82	129

Exposure	Economic* 1	Economic* 2	Total
Inexp.	20	28	48
Exp.	8	30	38
Control	19	24	43
Total	47	82	129

Hepatitis	Age <40 Yrs.	Age ≥ 40 Yrs.	Total
Negative	32	32	64
Positive	15	50	65
Total	47	82	129

Hepatitis	Economic* 1	Economic* 2	Total
Negative	21	43	64
Positive	26	39	65
Total	47	82	129

Economic*	Race Black	Race White	Total
1	14	33	47
2	16	66	82
Total	30	99	129

Hepatitis	Exposure Inexp.	Exposure Exp.	Exposure Control	Total
Negative	28	19	17	64
Positive	20	19	26	65
Total	48	38	43	129

Association of Exp. and Hep. (not adjusted).
$X_2^2 = 2.4$, $p = 0.25$

Association of Exp. and Hep. (adjusted for Age, Race, Soc.).
$X_2^2 = 1.12$, $p = 0.57$

*Economic Index 1 = (Income/Number of children + 1) <2
2 = (Income/Number of children + 1) ≥ 2

Inexp. = Inexperienced Wastewater Exposed
Exp. = Experienced Wastewater Exposed

TABLE 69. HEPATITIS A RESULTS FOR ALL EXPOSURE GROUPS IN MEMPHIS

Race	Age		
	<40 Yrs.	≥ 40 Yrs.	Total
Black	20	9	29
White	59	17	76
Total	79	26	105

Exposure	Race		
	Black	White	Total
Inexp.	8	37	45
Exp.	3	7	10
Control	18	32	50
Total	29	76	105

Economic*	Age		
	<40 Yrs.	≥ 40 Yrs.	Total
1	39	5	44
2	40	21	61
Total	79	26	105

Hepatitis	Race		
	Black	White	Total
Negative	10	66	76
Positive	19	10	29
Total	29	76	105

Exposure	Age		
	<40 Yrs.	≥ 40 Yrs.	Total
Inexp.	42	3	45
Exp.	8	2	10
Control	29	21	50
Total	79	26	105

Exposure	Economic*		
	1	2	Total
Inexp.	25	20	45
Exp.	4	6	10
Control	15	35	50
Total	44	61	105

Hepatitis	Age		
	<40 Yrs.	≥ 40 Yrs.	Total
Negative	65	11	76
Positive	14	15	29
Total	79	26	105

Hepatitis	Economic*		
	1	2	Total
Negative	29	47	76
Positive	15	14	29
Total	44	61	105

Economic*	Race		
	Black	White	Total
1	14	30	44
2	15	46	61
Total	29	76	105

Hepatitis				
	Inexp.	Exp.	Control	Total
Negative	38	7	31	76
Positive	7	3	19	29
Total	45	10	50	105

Association of Exp. and Hep. (not adjusted).
$X_2^2 = 5.21$, $p = 0.07$

Association of Exp. and Hep. (adjusted for Age, Race, Soc.)
$X_2^2 = 1.02$, $p = 0.60$

*Economic Index 1 = (Income/Number of children + 1) <2
2 = (Income/Number of children + 1) ≥ 2

Inexp. = Inexperienced Wastewater Exposed
Exp. = Experienced Wastewater Exposed

TABLE 70. HEPATITIS A RESULTS FOR ALL CITIES COMBINED AND FOR ALL EXPOSURE GROUPS

Race	Age <40 Yrs.	Age ≥ 40 Yrs.	Total
Black	99	99	189
White	146	111	257
Total	245	201	446

Exposure	Race Black	Race White	Total
Inexp.	30	102	132
Exp.	82	80	162
Control	77	75	152
Total	189	257	446

Economic*	Age <40 Yrs.	Age ≥ 40 Yrs.	Total
1	132	85	217
2	113	116	229
Total	245	201	446

Hepatitis	Race Black	Race White	Total
Negative	59	169	228
Positive	130	88	218
Total	189	257	446

Exposure	Age <40 Yrs.	Age ≥ 40 Yrs.	Total
Inexp.	102	30	132
Exp.	77	85	162
Control	66	86	152
Total	245	201	446

Exposure	Economic* 1	Economic* 2	Total
Inexp.	66	66	132
Exp.	83	79	162
Control	68	84	152
Total	217	229	446

Hepatitis	Age <40 Yrs.	Age ≥ 40 Yrs.	Total
Negative	166	62	228
Positive	79	139	218
Total	245	201	446

Hepatitis	Economic* 1	Economic* 2	Total
Negative	98	130	228
Positive	119	99	218
Total	217	229	446

Economic*	Race Black	Race White	Total
1	117	100	217
2	72	157	229
Total	189	257	446

Hepatitis	Exposure Inexp.	Exposure Exp.	Exposure Control	Total
Negative	89	76	63	228
Positive	43	86	89	218
Total	132	162	152	446

Association of Exp. and Hep. (not adjusted).
$X_2^2 = 20.02$, $p = 0.0001$

Association of Exp. and Hep. (adjusted for Age, Race, Soc.).
$X_2^2 = 1.65$, $p = 0.44$

*Economic Index 1 = (Income/Number of children + 1) < 2
2 = (Income/Number of children + 1) ≥ 2

Inexp. = Inexperienced Wastewater Exposed
Exp. = Experienced Wastewater Exposed

TABLE 71. ANTIBODY TO HEPATITIS A (ANTI-HAV) BY WASTEWATER EXPOSURE LOCATION, AGE, RACE AND SOCIOECONOMIC STATUS

Co-variable	No. of Workers Positive	Negative	p-Value*
Wastewater exposure			
Inexperienced	43	89	0.44
Experienced	86	76	
Control	89	63	
Location			
Cincinnati	124	88	0.04
Chicago	65	64	
Memphis	29	76	
Age			
<40 Years	79	166	0.0001
≥40 Years	139	62	
Race			
Black	130	59	<0.0001
White	88	169	
Economic index**			
Lower	119	98	0.07
Higher	99	130	
Length of exposure***			
<75 Months	32	42	0.15
≥75 Months	48	23	

*Multivariate chi-square analysis.

**Lower = Income ($1,000)/# children + 1 <2.
Higher = Income ($1,000)/# children + 1 ≥ 2.

***For experienced wastewater workers.

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TABLE 72. STATISTICAL ASSOCIATIONS* BETWEEN HEPATITIS A ANTIBODY AND COVARIABLES, ALL CITIES COMBINED AND BY CITY

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Effect**	All Cities	Cincinnati	Chicago	Memphis
		(probability values)		
Age and hepatitis	<0.0001	<0.0001	0.001	<0.0001
Age and race	0.70	0.90	0.70	0.34
Age and economic	0.004	0.41	0.09	0.001
Age and location	<0.0001	--	--	--
Race and hepatitis	<0.0001	<0.0001	0.13	<0.0001
Race and economic	0.003	0.002	0.23	0.95
Race and location	<0.0001	--	--	--
Economic and hepatitis	0.07	0.62	0.28	0.03
Economic and location	0.04	--	--	--
Location and hepatitis	0.04	--	--	--
Age, race and hepatitis	0.05	.32	.32	.38
Age, economic and hepatitis	0.02	0.04	0.29	0.19
Age, race and economic	0.92	0.71	0.18	0.05
Age, economic and location	0.04	--	--	--

*Multi-variate chi-square analysis.
**Adjusted for effect of other co-variables, three-way associations showing only where at least one $p \leq 0.05$.

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TABLE 73. SUMMARY OF ENTEROVIRUS NEUTRALIZING ANTIBODY TESTING PERFORMED

Virus	Worker Groups	Dates of Serum Collection	Previous Findings(1)
Polio I	Chicago: Inexperienced & experienced wastewater treatment plant workers	Nov. 1976, Feb. 1977 & May 1977	Isolation of virus in initial specimens from inexperienced workers in Aug., Sept. & Nov. 1976(2)
Polio II	Chicago: Inexperienced & experienced wastewater treatment plant workers	Nov. 1976, Feb. 1977 & May 1977	Isolation of virus in initial specimens from 2 inexperienced workers in Oct. 1976 & from 1 experienced worker in Nov. 1976
Coxsackie B2	Cincinnati: Experienced sewer maintenance & highway maintenance	Jan., Apr., July & Oct. 1976 & Jan. 1977	Isolation of virus from experienced wastewater treatment plant workers in July 1976(3)
Coxsackie B5	Cincinnati: Inexperienced wastewater-exposed, experienced wastewater treatment & sewer maintenance & highway maintenance	Feb., Apr., Aug. & Oct. 1978	Isolation of virus from experienced sewer maintenance worker in July 1978 specimen
Echo 3	Cincinnati: Inexperienced wastewater-exposed, experienced wastewater treatment & sewer maintenance & highway maintenance	Jan., Apr., July & Sept. 1977 & Jan. 1978	Isolation of virus in 7/77 and 9/77 from specimens from 2 inexperienced wastewater treatment workers after 0 & 6 months employment, respectively.
Echo 6	Cincinnati: Inexperienced wastewater-exposed, experienced sewer maintenance and highway maintenance	Jan., Apr., July & Oct. 1976 & Jan. 1977	Experienced sewer maintenance workers & highway maintenance workers had higher titer levels than experienced wastewater treatment plant workers, Apr. & Oct. 1976(4). Experienced sewer maintenance workers had more titer level increases Jan.-Oct. 1977 than other groups.

TABLE 73 (continued)

Virus	Worker Groups	Dates of Serum Collection	Previous Findings(1)
Echo 6	Chicago: Inexperienced & experienced wastewater treatment plant workers & waterworks employees	Feb., May, Aug., & Oct. 1977 & Jan. 1978	Jan. 1977 waterworks employees had higher titer levels than other groups

(1) Findings regarding virus isolations and titer level changes are based on data presented on pages 74, 75 and 84 of Final Report, Grant No. R 803643, unless noted otherwise.

(2) Worker with November 1976 isolation terminated employment before time of next specimen collection.

(3) Experienced workers recruited into study in July 1976 and therefore not available for testing in January 1976-January 1977 time period.

(4) Department of Environmental Health, University of Cincinnati Annual Report, March 31, 1978, pp. 209-217.

TABLE 74. SUMMARY OF 4-FOLD OR GREATER TITER LEVEL RISES

Virus	Time Period	Group	Total # Workers	# 4-fold or greater rises
Polio I	Nov. '76-May '77	Chicago Wastewwater Treatment Plant Workers:		
		Inexperienced		2
		Experienced		0
Polio II	Nov. '76-May '77	Chicago Wastewater Treatment Plant Workers:		
		Inexperienced		2
		Experienced		3
Coxsackie B2	Jan. '76-Jan. '77	Cincinnati:		
		Experienced Sewer Maintenance		1
		Highway Maintenance		3
Coxsackie B5	Feb.-Oct. '78	Cincinnati:		
		Inexperienced Wastewater-Exposed		0
		Experienced Wastewater Treatment		1
		Experienced Sewer Maintenance		1
		Highway Maintenance		0
Echo 3	Jan. '77-Feb. '78	Cincinnati:		
		Inexperienced Wastewater-Exposed		1
		Experienced Wastewater Treatment		2
		Experienced Sewer Maintenance		1
		Highway Maintenance		1

Table 74 (continued)

Virus	Time Period	Group	Total # Workers	# 4-fold or greater rises
Echo 6	Jan. '76-Jan. '77	Cincinnati:		
		Inexperienced Wastewater-Exposed		0
		Experienced Sewer Maintenance		1
		Highway Maintenance		1
Echo 6	Feb. '77-Jan. '78	Chicago:		
		Inexperienced Wastewater Treatment		2
		Experienced Wastewater Treatment		0
		Waterworks		0

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Titer Level Rises--

Due to the paucity of titer increases in three of the viruses, analyses of the 4-fold or greater rises were performed only for Polio III, Coxsackie B2, Echo 3, and Echo 6 (Cincinnati and Chicago combined). Comparisons were made among three "exposure" groups defined as follows: Exposure 1 = inexperienced wastewater-exposed workers; Exposure 2 = experienced wastewater-exposed workers; and Exposure 3 = controls.

Polio III. Analysis of the data from the observed frequency table for 4-fold and greater titer level rises (Table 75), by exposure group, race and age, revealed no significant differences among the exposure groups.

Coxsackie B2. The observed frequency table for 4-fold or greater titer level rises (Table 76) contains the breakdown of these titer level rises by exposure group, race and age group. With an adjustment for age and race the difference among groups was not significant.

Echo 3. Analysis of the observed frequency data for 4-fold or greater titer level rises (Table 77) by exposure group, race and age group did not reveal a significant difference among groups.

Echo 6. An observed frequency table for combined data from Cincinnati and Chicago is presented in Table 78. Adjusted for age and race, the results were not significantly different among groups.

Antibody Prevalence Differences--

Of the six viruses tested, results for only Echo 3 and Echo 6 (Cincinnati alone) showed any statistically significant difference for any of the time periods involved.

The titer levels for the Cincinnati workers tested were grouped by combining those of 8 and below into one group and 16 and above into a second group. Observed frequency tables for these data for Echo 3 for the five specimen collection periods are presented in Tables 79 through 83. Results for Echo 3 were statistically significant ($p \leq 0.05$) for 4 of the 5 periods and was close for the 5th, $p = 0.06$. For Echo 6, results are presented in Tables 84 through 88 and reveal differences ($p \leq .05$) for 3 of the 5 time periods.

The isolations of Echovirus 3 made from the inexperienced wastewater-treatment workers in July and September 1977 evidently were indicative of an infection among this group, although the small number of inexperienced workers tested (7) limits the interpretation of the data. The two workers from whom isolations were made were not included in the present serologic analyses because they were not in the study January 1977, the beginning of the 12-month period analyzed.

Experienced sewer maintenance workers had more titer level increases to Echovirus 6 in the 12-month period following the one examined. The differences in titer level prevalence detected in several of the time periods in the

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TABLE 75. OBSERVED FREQUENCY OF 4-FOLD AND GREATER TITER LEVEL RISES FOR POLIOVIRUS III (CHICAGO, NOVEMBER 1976 TO MAY 1977)

Exposure Group	4-Fold or Greater Rises	Race	Year of Birth 1	Year of Birth 2	Total
1	No	Black	3	2	5
		White	5	10	15
		Total	8	22	20
1	Yes	Black	1	0	1
		White	0	1	1
		Total	1	1	2
2	No	Black	0	3	3
		White	3	25	28
		Total	3	28	31
2	Yes	Black	0	1	1
		White	0	2	2
		Total	0	3	3

Total of the observed frequency table is 56.

Data adjusted for age and race ($\chi_1^2 = 0.02$, p = 0.88)

*1 = before 1939, 2 = 1939 or later.

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TABLE 76. OBSERVED FREQUENCY OF 4-FOLD AND GREATER TITER LEVEL RISES FOR COXSACKIE B2 (CINCINNATI JANUARY 1976-JANUARY 1977)

Exposure Group	4-fold or greater rise	Race	Year of Birth* 1	Year of Birth* 2	Total
2	No	Black	9	14	23
		White	0	1	1
		Total	9	15	24
	Yes	Black	0	1	1
		White	0	0	0
		Total	0	1	1
3	No	Black	7	15	22
		White	2	6	8
		Total	9	21	30
	Yes	Black	0	0	0
		White	1	2	3
		Total	1	2	3

Total of the observed frequency table is 58

Data adjusted for age and race ($\chi^2_1 = 0.17$, $p = 0.66$).

*1 = before 1939, 2 = 1939 or later.

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TABLE 77. OBSERVED FREQUENCY OF 4-FOLD OR GREATER TITER LEVEL RISES FOR ECHOVIRUS 3 (CINCINNATI JANUARY 1977-FEBRUARY 1978)

Exposure Group	4-fold or greater rise	Race	Year of Birth* 1	Year of Birth* 2	Total
1	No	Black	2	2	4
		White	1	1	2
		Total	3	3	6
	Yes	Black	0	0	0
		White	0	1	1
		Total	0	1	1
2	No	Black	15	17	32
		White	7	9	16
		Total	22	26	48
	Yes	Black	0	1	1
		White	2	0	2
		Total	2	1	3
3	No	Black	0	9	9
		White	2	11	13
		Total	2	20	22
	Yes	Black	1	0	1
		White	0	0	0
		Total	1	0	1

Total of the observed frequency table is 81

Data adjusted for age and race ($X_2^2 = 2.31$, $p = 0.32$).

*1 = before 1939, 2 = 1939 or later.

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TABLE 78. OBSERVED FREQUENCY OF 4-FOLD AND GREATER TITER LEVEL RISES FOR ECHOVIRUS 6 (CINCINNATI JANUARY 1976-JANUARY 1977, CHICAGO FEBRUARY 1977-JANUARY 1978)

Exposure Group	4-fold or greater rise	Race	Year of Birth* 1	2	Total
1	No	Black	4	1	5
		White	6	10	16
		Total	10	11	21
	Yes	Black	0	1	1
		White	0	0	0
		Total	0	1	1
2	No	Black	8	18	26
		White	3	22	25
		Total	11	40	51
	Yes	Black	1	0	1
		White	0	1	1
		Total	1	1	2
3	No	Black	8	23	31
		White	4	11	15
		Total	12	34	46
	Yes	Black	0	1	1
		White	0	0	0
		Total	0	1	1

Total of the observed frequency table is 122

Data adjusted for age and race ($X^2_2 = 0.84$, $p = 0.66$).

*1 = before 1939, 2 = 1939 or later.

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TABLE 79. OBSERVED FREQUENCY OF ECHOVIRUS 3 TITER LEVELS 8 & BELOW AND 16 & ABOVE (CINCINNATI JANUARY 1977)

Exposure Group	Titer Level*	Race	Year of Birth** 1	Year of Birth** 2	Total
1	1	Black	1	2	3
		White	0	2	2
		Total	1	4	5
	2	Black	1	0	1
		White	1	0	1
		Total	2	0	2
2	1	Black	13	18	31
		White	9	9	18
		Total	22	27	49
	2	Black	2	0	2
		White	0	0	0
		Total	2	0	2
3	1	Black	1	8	9
		White	2	11	13
		Total	3	19	22
	2	Black	0	1	1
		White	0	0	0
		Total	0	1	1

Total of the observed frequency table is 81

Summary Table:

Exposure Group	8 and Below Titers	16 and Above Titers
1	5	2
2	49	2
3	22	1

Data adjusted for age and race ($X_2^2 = 6.56$, p = 0.04).

*1 = 8 and below, 2 = 16 and above.

**1 = before 1939, 2 = 1939 and later.

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TABLE 80. OBSERVED FREQUENCY OF ECHOVIRUS 3 TITER LEVELS OF 8 & BELOW AND 16 & ABOVE (CINCINNATI APRIL 1977)

Exposure Group	Titer Level*	Race	Year of Birth** 1	Year of Birth** 2	Total
1	1	Black	1	2	3
		White	0	1	1
		Total	1	3	4
	2	Black	1	0	1
		White	1	1	2
		Total	2	1	3
2	1	Black	13	18	31
		White	9	9	18
		Total	22	27	49
	2	Black	2	0	2
		White	0	0	0
		Total	2	0	2
3	1	Black	1	8	9
		White	2	10	12
		Total	3	18	21
	2	Black	0	1	1
		White	0	1	1
		Total	0	2	2

Total of the observed frequency table is 81

Summary Table:

Exposure Group	8 and Below Titers	16 and Above Titers
1	4	3
2	49	2
3	21	2

Data adjusted for age and race ($X_2^2 = 9.30$, $p = 0.01$).

*1 = 8 and below, 2 = 16 and above.

**1 = before 1939, 2 = 1939 and later.

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TABLE 81. OBSERVED FREQUENCY OF ECHOVIRUS 3 TITER LEVELS OF 8 & BELOW AND 16 & ABOVE (CINCINNATI JULY 1977)

Exposure Group	Titer Level*	Race	Year of Birth** 1	2	Total
1	1	Black	1	2	3
		White	0	2	2
		Total	1	4	5
	2	Black	1	0	1
		White	1	0	1
		Total	2	0	2
2	1	Black	13	17	30
		White	8	9	17
		Total	21	26	47
	2	Black	2	1	3
		White	1	0	1
		Total	3	1	4
3	1	Black	1	6	7
		White	2	10	12
		Total	3	16	19
	2	Black	0	3	3
		White	0	1	1
		Total	0	4	4

Total of the observed frequency table is 81

Summary Table:

Exposure Group	8 and Below Titers	16 and Above Titers
1	5	2
2	47	4
3	19	4

Data adjusted for age and race ($X_2^2 = 5.72$, $p = .06$).

*1 = 8 and below, 2 = 16 and above.

**1 = before 1939, 2 = 1939 and later.

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TABLE 82. OBSERVED FREQUENCY OF ECHOVIRUS 3 TITER LEVELS OF 8 & BELOW AND 16 & ABOVE (CINCINNATI SEPTEMBER 1977)

Exposure Group	Titer Level*	Race	Year of Birth** 1	Year of Birth** 2	Total
1	1	Black	1	2	3
		White	0	2	2
		Total	1	4	5
	2	Black	1	0	1
		White	1	0	1
		Total	2	0	2
2	1	Black	13	18	31
		White	9	8	17
		Total	22	26	48
	2	Black	2	0	2
		White	0	1	1
		Total	2	1	3
3	1	Black	1	7	8
		White	1	10	11
		Total	2	17	19
	2	Black	0	2	2
		White	0	1	1
		Total	0	3	3

Total of the observed frequency table is 80

Summary Table:

Exposure Group	8 and Below Titers	16 and Above Titers
1	5	2
2	48	3
3	19	3

Data adjusted for age and race ($X^2 = 5.94$, $p = 0.05$).

*1 = 8 and below, 2 - 16 and above.

**1 = before 1939, 2 = 1939 and later.

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TABLE 83. OBSERVED FREQUENCY OF ECHOVIRUS 3 TITER LEVELS OF 8 & BELOW AND 16 & ABOVE (CINCINNATI FEBRUARY 1978)

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Exposure Group	Titer Level*	Race	Year of Birth** 1	Year of Birth** 2	Total
1	1	Black	1	1	2
		White	0	2	2
		Total	1	3	4
	2	Black	1	0	1
		White	1	0	1
		Total	2	0	2
2	1	Black	10	18	28
		White	9	9	18
		Total	19	27	46
	2	Black	2	0	2
		White	0	0	0
		Total	2	0	2
3	1	Black	0	7	7
		White	2	10	12
		Total	2	17	19
	2	Black	0	1	1
		White	0	1	1
		Total	0	2	2

Total of the observed frequency table is 75

Summary Table:

Exposure Group	8 and Below Titers	16 and Above Titers
1	4	2
2	46	2
3	19	2

Data adjusted for age and race ($X_2^2 = 7.25$, p = 0.03).

*1 = 8 and below, 2 = 16 and above.

**1 = before 1939, 2 = 1939 and later.

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TABLE 84. OBSERVED FREQUENCY OF ECHOVIRUS 6 TITER LEVELS OF 8 & BELOW AND 16 & ABOVE (CINCINNATI JANUARY 1976)

Exposure Group	Titer Level Group*	Race	Year of Birth** 1	Year of Birth** 2	Total
2		Black	4	9	13
		White	0	1	1
		Total	4	10	14
	2	Black	4	6	10
		White	0	0	0
		Total	4	6	10
3	1	Black	6	13	19
		White	2	7	9
		Total	8	20	28
	2	Black	1	2	3
		White	1	1	2
		Total	2	3	5

Total of the observed frequency table is 57

Summary Table:

Exposure Group	8 and Below Titers	16 and Above Titers
2	14	10
3	28	5

Data adjusted for age and race ($X_1^2 = 4.21$, $p = 0.04$).

*1 = 8 and below, 2 = 16 and above.

**1 = before 1939, 2 = 1939 and later.

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TABLE 85. OBSERVED FREQUENCY OF ECHOVIRUS 6 TITER LEVELS OF 8 & BELOW AND 16 & ABOVE (CINCINNATI APRIL 1976)

Exposure Group	Titer Level Group*	Race	Year of Birth** 1	2	Total
2	1	Black	7	9	16
		White	0	1	1
		Total	7	10	17
	2	Black	2	6	8
		White	0	0	0
		Total	2	6	8
3	1	Black	7	13	20
		White	2	7	9
		Total	9	20	29
	2	Black	0	2	2
		White	1	1	2
		Total	1	3	4

Total of the observed frequency table is 58

Summary Table:

Exposure Group	8 and Below Titers	16 and Above Titers
2	17	8
3	29	4

Data adjusted for age and race ($X_1^2 = 3.42$, $p = 0.06$).

*1 = 8 and below, 2 = 16 and above.

**1 = before 1939, 2 = 1939 and later.

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TABLE 86. OBSERVED FREQUENCY OF ECHOVIRUS 6 TITER LEVELS OF 8 & BELOW AND 16 & ABOVE (CINCINNATI JULY 1976)

Exposure Group	Titer Level Group*	Race	Year of Birth**		
			1	2	Total
2	1	Black	5	8	13
		White	0	1	1
		Total	5	9	14
	2	Black	4	7	11
		White	0	0	0
		Total	4	7	11
3	1	Black	7	13	20
		White	2	7	9
		Total	9	20	29
	2	Black	0	2	2
		White	1	1	2
		Total	1	3	4

Total of the observed frequency table is 58

Summary Table:

Exposure Group	8 and Below Titers	16 and Above Titers
2	14	11
3	29	4

Data adjusted for age and race ($X^2_1 = 6.52$, p = 0.01).

*1 = 8 and below, 2 = 16 and above.

**1 = before 1939, 2 = 1939 and later.

TABLE 87. OBSERVED FREQUENCY OF ECHOVIRUS 6 TITER LEVELS OF 8 & BELOW AND 16 & ABOVE (CINCINNATI SEPTEMBER 1976)

Exposure Group	Titer Level Group*	Race	Year of Birth** 1	Year of Birth** 2	Total
2	1	Black	7	8	15
		White	0	1	1
		Total	7	9	16
	2	Black	2	7	9
		White	0	0	0
		Total	2	7	9
3	1	Black	7	14	21
		White	2	7	9
		Total	9	21	30
	2	Black	0	1	1
		White	1	1	2
		Total	1	2	3

Total of the observed frequency table is 58

Summary Table:

Exposure Group	8 and Below Titers	16 and Above Titers
2	16	9
3	30	3

Data adjusted for age and race ($X_1^2 = 6.14$, $p = 0.01$).

*1 = 8 and below, 2 = 16 and above.

**1 = before 1939, 2 = 1939 and later.

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TABLE 88. OBSERVED FREQUENCY OF ECHOVIRUS 6 TITER LEVELS OF 8 & BELOW AND 16 & ABOVE (CINCINNATI FEBRUARY 1977)

Exposure Group	Titer Level Group*	Race	Year of Birth** 1	2	Total
2	1	Black	7	10	17
		White	0	1	1
		Total	7	11	18
	2	Black	2	4	6
		White	0	0	0
		Total	2	4	6
3	1	Black	2	11	13
		White	1	7	8
		Total	3	18	21
	2	Black	0	1	1
		White	1	0	1
		Total	1	1	2

Total of the observed frequency table is 47

Summary Table:

Exposure Group	8 and Below Titers	16 and Above Titers
2	18	6
3	21	2

Data adjusted for age and race ($X_1^2 = 1.38$, p = p = 0.24).

*1 = 8 and below, 2 = 16 and above.

**1 = before 1939, 2 = 1939 and later.

January 1976-January 1977 period suggest that an infection among these workers may have occurred in both 1976 and 1977.

Gastrointestinal Illnesses

In the 1975-78 seroepidemiologic study, inexperienced wastewater workers were found to have reported gastrointestinal illnesses at about twice as high a rate as the other work groups. Serologic analyses performed at that time were unable to determine the causative agent(s) involved. In an attempt to elucidate the etiologic agent(s) involved, paired sera bracketing in time reported episodes of gastrointestinal illnesses, were analyzed for antibody to Norwalk agent and rotavirus. Both of these agents have been reported to cause gastrointestinal illness. The age and race characteristics of the 48 male workers included in these analyses are shown in Table 89.

Norwalk Agent. Paired sera from the group of 48 workers with gastroenteritis were tested for antibody to the Norwalk agent. Infection, as indicated by 4-fold or greater increases in antibody, did not differ among the groups tested. Four-fold or greater titer level increases occurred in four of 30 inexperienced workers with gastroenteritis, none of 13 controls, and none of 5 experienced workers. All of the infections occurred in the first two quarters of the year. Two of the infections occurred in Chicago, one in Cincinnati and one in Memphis. These results indicate that at least 13% (4 of 30) of the cases of gastroenteritis in inexperienced workers may be associated with Norwalk agent.

Data relating to titer level, worker group, season of year, age, race, wastewater exposure, aerosol exposure, and job classification pertaining to the second samples tested from each worker were analyzed by analysis of covariance. In the analysis of covariance model the categorial variables (location, race and exposure group) were treated as class variables. Two job classification groups were used: laborers, and others. A logarithmic-type coding of the titer levels were used in the analyses (<100=1, 100=2, 200=3, 400=4, 800=5, etc.). Wastewater and aerosol exposure categories were used in the analyses of data from the inexperienced and experienced wastewater-exposed workers. Results of the analysis of the second sera analyzed for each worker (Table 90) indicate that the inexperienced workers had higher levels than the experienced and control workers ($p = 0.03$) and that those with high and medium aerosol exposure had higher titers than those in the low aerosol category ($p = 0.08$). Black workers had higher levels than white workers ($p = 0.06$). The reason for using covariance was to remove bias due to age, race, age, race, etc. Therefore, the differences observed among experience and aerosol exposure categories were independent of the racial difference.

Rotavirus. Rotavirus antibody was measured by an enzyme immunoassay using SA-11 virus. Two of the 30 inexperienced workers (7%) and two of the experienced workers (40%) had four-fold or greater increases in rotavirus antibody. None of the controls had documented rotavirus infection. Analysis of covariance was performed on the rotavirus data in the same fashion as for the Norwalk agent titer levels (<100=1, 100=2, etc.). The results (Table 91) indicate that titer levels from Cincinnati and Chicago workers tended to be higher than those from Memphis ($p = 0.07$) but that no significant differences

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TABLE 89. AGE AND RACE CHARACTERISTICS OF WORKERS TESTED FOR ANTIBODY TO NORWALK AGENT AND ROTAVIRUS

Group	No. of Workers White	No. of Workers Black	Average Age Years
Location:			
Cincinnati	10	4	35.2
Chciago	13	6	43.8
Memphis	14	1	29.7
Experience:			
Inexperienced	24	6	30.4
Experienced	2	3	45.4
Controls	11	2	48.8
Wastewater Exposure*			
Low	9	6	38.4
Medium	4	0	27.8
High	13	3	28.2
Aerosol Exposure*			
Low	10	3	30.1
Medium	7	3	31.3
High	9	3	36.2

*Includes only inexperienced and experienced wastewater-exposed workers.

TABLE 90. ANTIBODY TITERS TO NORWALK AGENT IN SINGLE SERUM SAMPLES AS ANALYZED BY WORKER GROUP, SEASON AND DEMOGRAPHIC VARIABLES

Variable		Mean ± Standard Error*	N	p-Value**
All Workers				
Location:	Cincinnati	3.07 ± .54	14	0.39
	Chicago	2.89 ± .46	19	
	Memphis	1.67 ± .52	15	
Experience:	Inexperienced	3.13 ± .38	30	0.03
	Experienced	1.80 ± .88	5	
	Control	1.54 ± .54	13	
Race:	White	2.22 ± 0.33	37	0.06
	Black	3.73 ± 0.60	11	
Age:	(Slope)	0.0166 ± 0.0303	48	0.59
Job classification and season not significant				
Wastewater Workers				
Location:	Cincinnati	3.27 ± 0.68	11	0.17
	Chicago	3.36 ± 0.60	14	
	Memphis	2.00 ± 0.71	10	
Wastewater Exposure	Low	2.73 ± 0.60	15	0.40
	Medium	3.25 ± 1.16	4	
	High	3.06 ± 0.58	16	
Aerosol Exposure	Low	1.63 ± 0.57	13	0.08
	Medium	4.10 ± 0.65	10	
	High	3.42 ± 0.59	12	
Race:	White	2.54 ± 0.43		0.06
	Black	4.11 ± 0.73	9	
Age:	(Slope)	0.05 ± 0.05	35	0.33
Job classification and season not significant.				

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*Values represent titer levels categorized as follows: 100=1, 100=2, 200=3, 400=4, 800=5, etc.

**Multivariate chi-square analysis.

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TABLE 91. ANALYSIS OF ROTAVIRUS ANTIBODY TEST RESPONSE BY WORKER GROUP, SEASON, AND DEMOGRAPHIC VARIABLES

Variable		Mean ± Standard Error	N	p-Value
All Workers				
Location:	Cincinnati	4.43 ± 0.50	14	
	Chicago	3.84 ± 0.43	19	0.07
	Memphis	2.33 ± 0.49	15	
Experience:	Inexperienced	3.80 ± 0.35	30	
	Experienced	4.80 ± 0.87	5	0.59
	Control	2.46 ± 0.54	13	
Race:	White	3.16 ± 0.32	37	0.21
	Black	4.82 ± 0.58	11	
Age:	(Slope)	-0.0187 ± 0.0344	48	0.59
Job classification and season not significant.				
Wastewater Workers				
Location:	Cincinnati	5.09 ± 0.54	11	
	Chicago	3.77 ± 0.48	14	0.14
	Memphis	3.00 ± 0.57	10	
Wastewater Exposure:	Low	4.53 ± 0.50	15	
	Medium	3.50 ± 0.96	4	0.33
	High	3.50 ± 0.48	16	
Aerosol Exposure:	Low	3.46 ± 0.54	13	0.72
	Medium	4.30 ± 0.62	10	
	High	4.17 ± 0.57	12	
Race:	White	3.65 ± 0.37	26	0.62
	Black	4.78 ± 0.63	9	
Age:	(Slope)	-0.07 ± 0.05	35	0.16
Job classification and season not significant.				

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were detected among the three work experience groups, or by race, wastewater exposure, aerosol exposure, job classification or season.

Prototheca Antibody

One hundred-eighty-eight serum specimens from 110 Cincinnati-Chicago-Memphis study participants were analyzed in the laboratories at Northwestern University for IgG antibody to *Prototheca wickerhamii* algae (54,55). Single specimens were analyzed from experienced wastewater-exposed workers and paired specimens for inexperienced wastewater-exposed workers and controls. For experienced workers Quarter 14 sera (July 1978) were used when available; for inexperienced workers, both Quarter 14 and the first available sera were analyzed. Where possible, the control workers selected did not have exposure to street cleaning activities (Cincinnati), water basin sludge cleaning (Chicago) and water-filled man holes (Memphis). The 15 workers tested in the initial screening for prototheca are included in the total of 110 workers in the current testing.

Selection of workers to be tested was based on availability of serum, race, and sex. The race mix between each group within a particular city was the same. In Cincinnati the mix was 60% black, 40% white, for the experienced groups and 40% black, 60% white for the inexperienced; in Chicago the groups were 20% black, 80% white; and in Memphis the proportions were 30% black, and 70% white. In Chicago and Memphis the age composition for groups within each city was approximately equal. However, in Cincinnati, we were not able to select age matched groups of workers. The two groups of inexperienced workers (sewer maintenance and wastewater treatment), although similar in age to each other, are younger than the experienced workers. The race, median age and age range for the groups, is summarized in Table 92.

Results were expressed as counts per minute and for most sera duplicate analyses were performed. Prototheca antibody data from 110 workers consisting of 312 values were made available for statistical analysis. In addition to the above antibody response, age, race, sex, geographic location, exposure group and economic index information were also included in the analysis. The economic index was categorized into the two groups which were used in the hepatitis analysis. The same was done for age grouping.

An analysis of covariance was done among the above variables (Table 93). The logarithmic (base 10) transformation for prototheca response was found to be necessary for satisfying the need for a normal distribution. Considering all the data together the variables exposure group and economic category were significant at $p = 0.0274$ and 0.0093, respectively. Location, age, and race were not significant, with significance levels of $p = 0.5382$, $p = 0.7899$ and $p = 0.1843$, respectively.

Analysis of covariance for the three locations separately revealed that exposure group was only a significant co-variable in Chicago ($p = 0.0003$) where the experienced wastewater treatment workers and the water works employees had higher values than the inexperienced wastewater treat-

TABLE 92. DEMOGRAPHIC DATA ON 110 WORKERS TESTED FOR ANTIBODY TO PROTOTHECA ALGA

	No. of Workers	No. Sera per Worker	Age, Years*		Race	
			Median	Range	% Black	% White
Cincinnati						
Inexperienced Sewer Maintenance	10	2	28	24-46	40	60
Inexperienced Sewage Treatment	10	2	28	22-58	40	60
Experienced Sewage Treatment	10	1	38	28-51	60	40
Experienced Sewer Maintenance	10	1	38	26-51	60	40
Highway Maintenance	10	2	42	27-50	60	40
Chicago						
Inexperienced Sewage Treatment	10	2	50	32-60	20	80
Experienced Sewage Treatment	10	1	54	36-63	20	80
Water Works	10	2	54	34-62	20	80
Memphis						
Inexperienced Sewage Treatment	20	2	26	19-39	35	65
MLG&W	10**	2	27	21-34	30	70
Total no. of workers	110					

*Age in 1978.
**For two workers, data from only a single serum was analyzed.

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TABLE 93. RESULTS OF ANALYSIS OF CO-VARIANCE OF PROTOTHECA WICKERHAMII/IgG DATA

Co-Variable	Log_{10} Antibody Response		No. of
	Mean	Standard Error	Determinations
All Groups Combined			
Exposure Group			
Inexperienced wastewater-exposed	4.677[a]	0.023	163
Experienced wastewater-exposed	4.782[a]	0.034	57
Controls	4.742[a]	0.029	92
Location: Cincinnati	4.705	0.027	120
Chicago	4.711	0.029	93
Memphis	4.733	0.028	99
Age: $<$40 Years	4.721	0.021	184
$\geq$40 Years	4.708	0.026	128
Economic: Lower	4.678[b]	0.025	154
Higher	4.753[b]	0.021	158
Race: Black	4.736	0.030	104
White	4.705	0.019	208
Time: Earlier quarter	4.679	0.026	118
Later quarter	4.717	0.027	118
Cincinnati			
Economic: Lower	4.655[c]	0.035	74
Higher	4.785[c]	0.039	46
Chicago			
Exposure Group			
Inexperienced wastewater-exposed	4.591[d]	0.037	40
Experienced wastewater-exposed	4.867[d]	0.067	19
Water works	4.765[d]	0.046	34
Race: Black	4.834[e]	0.050	19
White	4.680[e]	0.033	74

a, p = 0.03; b, p = 0.009; c, p = 0.003; d, p = 0.0003; e, p = 0.02.

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ment plant workers. Race was also a significant co-variable in Chicago ($p = 0.02$) (white workers higher) and economic index was a significant co-variable in Cincinnati ($p = 0.003$). No differences were detected between the results of the analysis of the earlier sera tested and the later sera tested. Prototheca antibody responses for the individual participants are listed in Tables 94 to 96 for Cincinnati, Chicago and Memphis, respectively. Although exposure group was a significant co-variable, the fact that values for the control group were almost as high as those for the experienced wastewater workers suggests that wastewater exposure itself was not a factor.

SUMMARY AND DISCUSSION

A previous report on a prospective sero-epidemiologic study of workers occupationally-exposed to wastewater revealed an increase in episodes of gastrointestinal illness among recently hired workers. However no consistent laboratory evidence was detected of increased bacterial or viral infections, as indicated by cultures or antibody surveys. Using a serum bank established in the earlier study, the present study evaluated possible viral factors that may be involved in the gastrointestinal illnesses and performed additional serologic tests involving analysis for antibody to Hepatitis A virus (anti-HAV).

Analysis of paired sera from workers who reported gastrointestinal illness indicated that among inexperienced workers Norwalk agent was associated temporally with 13% of these illnesses and rotavirus with 7%. Inexperienced wastewater-exposed workers had higher levels of antibody to Norwalk agent than did experienced and control workers ($p = 0.03$). The presence of anti-HAV was not different among the inexperienced wastewater workers, experienced wastewater workers, and controls and was not associated with length of wastewater exposure for the exposed wastewater workers. However, anti-HAV was found to be associated with race ($p \leq 0.0001$) and age ($p\ 0.001$).

The failure to detect an increased risk of Hepatitis A from wastewater exposure in the present study compared to the finding of such an increase in workers in Anchorage (48) and in Copenhagen (46), may be due to higher exposures for the latter two groups. The former were exposed to an open sludge process and the latter to conditions in a very old sewer system and in an enclosed aerated grit chamber with high levels of air contamination. The inability to detect an increase in parasite infections among Cincinnati sewer maintenance workers (60) while such has been found in other wastewater-exposure groups (61,62) may also be due to lower exposure levels or to lower prevalence rates in the local population. As has been found elsewhere (46,58,59), the presence of anti-HAV was positively associated with age, in each city separately and for all cities combined ($p \leq 0.001$). However, the finding of an association with race that was independent of economic status has not been previously reported.

Overall there appears to be only a limited risk of viral and bacterial infection in the workers we studied. A similar conclusion was reached for

TABLE 94. RESULTS OF TESTING FOR ANTIBODY TO PROTOTHECA WICKERHAMII/IgG (COUNTS PER MINUTE) CINCINNATI PARTICIPANTS

Inexperienced Sewer Maintenance		Inexperienced Wastewater Treatment		Experienced Wastewater Treatment	Experienced Sewer Maintenance	Highway Maintenance	
1st Specimen Tested	Quarter 14	1st Specimen Tested	Quarter 14	Quarter 14	Quarter 14	1st Specimen Tested	Quarter 14
87,927	107,310	19,142	25,153	67,931	36,581	19,194	25,675
66,538	32,749	147,883	144,677	92,881	102,474	41,198	63,167
17,753	32,754	15,843	92,913	23,420	33,314	32,485	56,991
71,952	85,192	49,148	28,658	118,110	126,031	41,816	27,767
35,279	65,849	53,651	33,749	61,320	40,441	25,759	32,120
243,323	83,526	26,061	30,033	59,248	50,382	35,723	46,570
72,854	146,641	135,530	113,716	76,730	94,536	124,816	149,274
72,454	84,765	38,304	42,532	30,925	56,646	142,097	177,317
211,170	247,707	98,462	89,579	38,086	29,178	92,618	92,293
21,963	26,712	30,813	49,477	48,920	34,790	177,317	197,602
Avg.82,876	91,320	61,484	69,049	61,757	60,437	73,302	86,880

Results are averages of duplicate analyses of each specimen.

Pooled sera controls: 37,912.

Low pool - 37,700, mid pool - 96,380 and high pool - 164,304.

TABLE 95. RESULTS OF TESTING FOR ANTIBODY PROTOTHECA WICKERHAMII/IgG (COUNTS PER MINUTE) CHICAGO PARTICIPANTS

Inexperienced Wastewater Treatment Plant Workers		Experienced Wastewater Treatment Plant Workers	Water Works Employees	
1st Specimen Tested	Quarter 14	Quarter 14	1st Specimen Tested	Quarter 14
76,531	69,633	69,396	67,264	70,529
41,959	36,203	155,750	91,525	49,792
17,165	15,753	168,001	33,752	26,056
29,114	18,393	33,929	49,106	80,947
70,152	53,291	82,613	103,768	134,052
47,809	37,437	39,238	25,752	25,559
52,878	82,951	51,196	98,500	202,324
18,866	28,582	48,952	76,841	111,452
53,392	69,250	195,175	105,585	52,593
29,030	37,450	41,020	32,898	34,758
Avg. 43,690	44,894	88,527	68,499	78,806

Results are averages of duplicate analysis of each specimen.

Pooled sera controls: 37,912.

Low pool - 37,700, mid pool - 96,380, and high pool - 167,304.

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TABLE 96. RESULTS OF TESTING FOR ANTIBODY TO PROTOTHECA WICKERHAMMI/IgG (COUNTS PER MINUTE) MEMPHIS PARTICIPANTS

Inexperienced Wastewater Treatment Plant Workers 1st Specimen Tested	Quarter 14	Memphis Light, Gas & Water Workers 1st Specimen Tested	Quarter 14
10,268	11,664		36,802
38,986	50,072	33,799	51,690
31,990	36,483	67,291	87,797
54,929	42,098		48,928
101,171	94,987	68,112	30,230
17,388	35,684	59,696	116,743
39,826	19,863	53,796	40,268
65,627	37,318	64,804	79,532
60,191	55,339	26,054	22,272
47,417	70,116	26,609	33,072
49,021	55,300		
107,818	139,223		
220,163	167,643		
41,753	61,052		
39,539	65,285		
138,124	112,252		
40,450	57,370		
138,089	161,660		
40,258	47,912		
49,305	54,677		
Avg. 66,615	68,800	50,028	54,733

Results are averages of duplicate analysis of each specimen.

Pooled sera controls: 37,912.

Low pool - 37,700, mid pool - 96,380 and high pool - 167,304.

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the risk of viral infection among workers at a wastewater spray irrigation site (63). However, based on reports elsewhere (46,48,61,62), it appears that a risk may exist in some situations.

SECTION 6

MORTALITY STUDY OF FORMER EMPLOYEES OF THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

During 1978-79 a mortality study was initiated of former employees of the Metropolitan Sanitary District of Greater Chicago (MSD). The criteria for inclusion in this study were that the worker's employment was to have included at least some period of time during the 1960's; that he/she be deceased as of December 31, 1976; and have a total length of employment of at least six months. In an interim report in 1979 of 402 decedents (4) no statistically significant differences ($p \leq .05$) between observed and expected number of deaths were revealed for five causes of death (neoplasms, heart disease, diseases of the respiratory system, accidents and other). Comparisons were made for all 402 workers, for three length of employment categories, for three departments and for five job classifications. In the only other known mortality study of wastewater-exposed workers, three pancreatic cancers were noted in an analysis involving 33 deceased Copenhagen sewer workers, representing an excess over the number expected, 0.4 (64).

METHODS

For the present analyses, death certificates and employment records were available at the time of the start of the analysis for 815 decedents. Using MSD personnel files and those of the Sanitary District Employees' and Trustees Annuity and Benefit Fund of Chicago, it was determined that there were a total of 3963 people who worked for MSD at some time during the 1960's. Of this total, 788 were employed for less than six months leaving a cohort of 3175. MSD personnel and pension fund records supplemented by those of Social Security and the Illinois Motor Vehicle Bureau were used to establish the vital status of the cohort of 3175 (Table 97). Most of the vital status information for the study was obtained directly from the MSD pension fund office. Social Security records were used to establish: (1) whether contributions were still being made to a particular social security number, (2) whether the social security participant was receiving benefits or (3) whether a beneficiary had/was receiving benefits. For the first two categories the worker was assumed to be alive and for the third, deceased. Social Security numbers for a total of 864 cohort members were sent to the Social Security Administration during the course of the study. For this group vital status was determined for about 70% with 60% known to be alive and 10% known to be deceased. Illinois Motor Vehicle Bureau Records were used to determine if a person had renewed his/her drivers license since December 31, 1976 and if so, was therefore presumed to be alive. If a drivers license had not been renewed, the vital status would remain unknown. Date of birth for 1195 cohort members were sent to the Motor Vehicle Bureau for this purpose. About 39%

TABLE 97. VITAL STATUS OF MORTALITY STUDY COHORT

Total number 1960's employees	3963
Number who worked < 6 months	788
Cohort size	3175
Known alive	1543
Died after study cut-off-date 12/31/76	133
Known dead at study cut-off of 12/31/76	897
Unknown vital status	602

were found to have renewed their drivers license since 1977. Letters to the last known address of about 50 cohort members were used in some cases to obtain information on vital status (Appendix J). Vital status was determined for 81% of the cohort members. In an effort to determine if the demographic characteristics differed for the cohort members with known and unknown vital status, a comparison was made between the characteristics for which data was available. Based on vital statistics tables for the United States, it was expected that there should be about 1000 decedents in the cohort by December 31, 1976. Since the search for vital status has continued beyond the date when statistical analyses of available data was initiated, 897 of the cohort are known deceased at the time of writing compared to the 815 in the data analyses. Death certificates for the additional 82 known decedents are in the process of being assembled for future use. In addition, about 100 death certificates are available from cohort members who were alive at the time of the study cut-off date, December 31, 1977, but who have since become deceased. The present data analysis, however, is limited to the 815 decedents. Most of the death certificates were obtained from the MSD pension fund files, with additional ones being obtained from Cook County Bureau of Vital Statistics and various state vital statistics bureaus.

Aside from the availability of over twice as many cases as in the interim report, the present study differs from the first in that more numerous cause of death categories are considered, expected causes of death are adjusted for both race and sex and the use of employment history data is more extensive. In the interim study only five general categories of cause of death were used while in the present study the neoplasms category is also subdivided into 10 site-specific groups.

Causes of Death

For each of the 815 decedents, the underlying causes of death from the death certificates were classified and coded by a qualified nosologist, according to the 8th Revision of the International Classification of Diseases (ICD) (65). All classifications and codings were performed by the same person. The cause-of-death groups are neoplasms (ICD codes 140-209), heart disease (ICD codes 390-448), respiratory disease (ICD codes 470-493), accidents (ICD codes E800-949), and other causes. For neoplasms the underlying causes of death were further grouped according to pancreatic cancer (ICD codes 157-157.9), leukemia (ICD codes 204-207.9) buccal cavity neoplasms (ICD codes 140-149.9), digestive tract neoplasms (ICD codes 150-159.9), respiratory system neoplasms (ICD codes 160-163.9), breast neoplasms (ICD codes 174-174.9), genital neoplasms (ICD codes 180-187.9), urinary tract neoplasms (ICD codes 188-189.9), lymph neoplasms (ICD codes 200-203.9 and 208-209.9) and unspecified neoplasms (ICD codes 170-173.9 and 190-199.9).

Statistical Analysis

The observed number of deaths for the various cause-of-death groupings was compared with the expected number of deaths which was determined from vital statistics records for the State of Illinois, stratified by age (5 year intervals), race, sex and year of death. The procedure used to determine the expected number of deaths is shown in Appendix K. For pancreatic cancer, the expected number of deaths was based on vital statistics for the entire U.S. since they were not available for Illinois. The observed and expected number of decedents were compared using proportionate mortality analyses (66) which as a final step used the chi-square and binomial tests (56) in order to determine statistical significance. Where expected values are less than 5, the accuracy of the X^2 test is reduced and the preferred test is the binomial (ref. 56, Section 7.7, pages 115-118). Since we didn't know whether all death certificates had been obtained for cohort members we couldn't use the standard mortality ratios (SMR) method with confidence. The SMR method would have reduced the probability of detecting significant effects.

In an effort to expand the number of specific causes of death examined, data for the 815 decedents were analyzed by an existing computer program involving 54 causes of death and based on U.S. Vital Statistics (67). Individual causes of death for which the observed number of deaths was significantly different from expected ($p \leq .05$) were then examined using Illinois Vital Statistics.

Employment History

Employment history of the decedents was coded according to length of employment, job location, job classification, organization function, and for workers at the three largest wastewater treatment plants, certain characteristics of the waste treatment process utilized during the specific years of individual workers' employment. The latter characteristics included wastewater flow, sludge treatment process employed and output of heat-dried sludge. Although the three largest MSD wastewater treatment plants each now employs the activated sludge wastewater treatment process, they differ considerably in size and each has evolved historically in somewhat different ways. The plants are probably the most different with respect to sludge treatment history. For example, sludge from the Northside Plant (Skokie) has always been conveyed by pipeline to the West-Southwest Plant (Cicero) for treatment. The West-Southwest Plant has historically utilized a variety of sludge treatment operations, some in parallel and some in series: anaerobic digestion, open air sludge drying beds, vacuum filtration, heat drying, land application, wet-air oxidation, and incineration. All but the latter two are still in use today. The land application of sludge on MSD-owned land in Fulton County, Illinois was initiated for sludge from the West-Southwest and Calumet Plants in 1970. The heat drying of sludge at the Calumet Plant was initiated in 1937 and discontinued in 1962. The ultimate use of heat dried sludge is for the organic enrichment of soil. A summary of some of the key historic treatment characteristics of these three plants is presented in Table 98.

Length of Employment. Four length of employment categories were used, 6 months to 10 years, 11-20 years, 21-30 years and 31 or more years.

Job Location. The five job locations utilized were the three largest wastewater treatment plants (West-Southwest, Calumet and Northside), the downtown Chicago administrative offices and an other category. The latter included the smaller wastewater treatment facilities, the sanitary canals and other waterways, variable job locations and indeterminant job locations. The current MSD organizations code system (Appendix L) was used as the basis for establishing the specific code numbers for these job locations (Appendix M).

Job Classification. Seven job classification categories were developed: Maintenance Laborer A (including A-shift), Maintenance Laborer B, Fireman-Oiler, Operating Personnel (including safety and security personnel), Engineers (including architects, draftsmen and laboratory personnel), Tradesmen and Other. Each job classification, coded as "classification," corresponded to one and only one of the seven categories. The 1978 MSD alphabetical list of job titles (Appendix N) was used as the basis for assigning each worker to a particular job classification. The specific job classification code numbers for each of the seven categories described above is contained in Appendix O. Maintenance Labor A, A-shift, and B and Fireman-Oiler are each specific MSD job titles.

Organizational Function. Five categories of functions were developed: Research and Development; Engineering; Maintenance, Security and Safety; Treatment Operations; and Administrative (Appendix P). Assignment to a particular category was based upon the function as suggested by the title of the organizational unit. For example, all administration units, even if they were in the Engineering or Maintenance and Operations were placed in the Administration category. Similarly any unit with an engineering function, even if it was in the Maintenance and Operations Department was assigned to the engineering function category.

Heat Dried Sludge

Cumulative Production. At two of the three largest MSD wastewater treatment plants, West-Southwest and Calumet, facilities for the heat drying of sludge were in operation for all or part of the study period (Table 98). Thus, each worker at these treatment plants and at the downtown location could be assigned a crude heat dried sludge index which was the sum of the average daily amount of sludge dried (tons/day) for each year of employment. For workers at the Northside wastewater treatment plant and at the downtown Chicago location this index was therefore zero. Cohort members in the "variable, indeterminant and other" job locations category were not used in this comparison or in the two following ones: years of dried sludge production and wastewater flow. Workers were then grouped into three categories: 0 tons/day, 1-5,000 tons/day and more than 5,000 tons/day.

Total Years Production. Each worker at the 3 largest wastewater treatment plants and at the downtown location was also assigned a number equal to the total number of years of employment at a location where the heat drying of sludge was being practiced. Workers were then grouped into three crude categories of "sludge heat drying years": 0, 1-14 years, 15 and more years.

Wastewater Flow

A wastewater flow factor was assigned each worker at the three largest wastewater treatment plants and at the downtown location based on the sum of the yearly daily average wastewater treated at the location where employed. All workers at the downtown location had a zero factor assigned them since no wastewater is treated at that location. Workers were then categorized into

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TABLE 98. SELECTED HISTORIC CHARACTERISTICS OF TREATMENT OPERATION AT WEST-SOUTHWEST, CALUMET AND NORTHSIDE PLANTS

Plant, average flow and initial year of operation	Wastewater treatment processes	Sludge treatment processes	Other features
West-Southwest (850 MGD-1960's average, init. op. 1930)	Imhoff treatment (1930 to 1938) Activated sludge treatment (1939 to date)	Air drying (1930 to date) Heat drying (1939 to date) Wet air oxidation (1967 to 1977) Anaerobic digestion (1940 to date) Land application (1970 to date)	Coal use discontinued (1968) Afterburner installed on heat drying plant (1971)
Calumet (150 MGD-1960's average, init. op. 1922)	Imhoff treatment (1922 to 1935) Activated sludge treatment (1936 to date)	Heat drying (1937 to 1964) Anaerobic digestion (1965 to date) Land application (1970 to date)	
Northside (280 MGD-1960's average, init. op. 1928)	Imhoff treatment (1928 to 1934) Activated sludge (1935 to date)	Sludge pumped to West-Southwest plant	

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three groups: 0-4,000 million gallons/day (MGD); 4,001-12,000 MGD; and more than 12,000 MGD.

Table 99 contains a summary of the number of categories of cause of death and employment history used in the present study and the 1979 interim report.

RESULTS

Comparison of cohort members with known and unknown vital status were made for sex and job classification (Table 100) and length of employment and year of birth (Table 101). There was a higher percentage of Maintenance Laborer B workers and a lower percentage of workers in unknown job classification in the unknown vital status group than in the known vital status group (Table 100). A significant difference was found for length of experience (p = 0.0001) and for year of birth (p = 0.0001) (Table 101). 94% of the sample of unknown vital status cohort members had less than 10 years of employment compared to only 55% of the cohort with known vital status. 39% of the known vital status group were born before 1906 compared to only 16% of the unknown status group. No differences in sex were detected (Table 100).

Of the 815 decedents, 94 percent are white male (764), 2 percent white female (15), and 4 percent black males (36). There were no black females in the group. Age of death for white male, white female and black male deceased cohort members is presented in Table 102.

A comparison of observed and expected number of deaths among the decedents for the five major cause-of-death groupings (Table 103) using Illinois Vital Statistics revealed (p = 0.12) more than the expected number of deaths for neoplasms and other causes and less than the expected number for diseases of the respiratory system and accidents. The comparison of observed and expected number of deaths for subdivisions of the neoplasm causes-of-death (Table 104) revealed a statistically significant increase in leukemia as a cause of death, 11 observed deaths compared to 6.07 expected (p = 0.045). The confidence interval for the observed/expected ratio of 1.8 is ± 0.8.

Based on the comparisons with U.S. Vital Statistics, the observed number of deaths was significantly different than expected for two causes of death: leukemia (ICD 204-207) (p = 0.045) and pneumonia (ICD 480-486.9) (p = 0.02) and close to significantly different (p = 0.08) for esophageal cancer (ICD 150-150.9). For leukemia there were more deaths than expected and for pneumonia, fewer than expected. Using Illinois data the ratio of observed to expected number of deaths due to esophageal cancer (1.89) was slightly less than that using U.S. data (2.11) and the significance level slightly higher (p = 0.13), while the excess in leukemia was significant as previously indicated (p = .045). The fewer deaths observed for pneumonia was still significant (p = .02) using Illinois data. The results of these comparisons, using both U.S. and Illinois data, are presented in Table 105. Included in the causes of death examined with U.S. vital statistics was "infective and parasitic diseases" (ICD 000-139) for which only one-half the expected number of deaths were observed.

Because of the excess of observed over expected number of deaths from leukemia, and the fewer than expected deaths from pneumonia comparisons

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TABLE 99. COMPARISON OF CAUSE OF DEATH AND EMPLOYMENT HISTORY CATEGORIES OF PRESENT ANALYSIS WITH THOSE IN 1979

	Number of Categories	
Category type	Present analysis	1979 Interim report
Causes of death*		
General groupings	5	5
Neoplasm subgroups	11	1 (pancreatic cancer)
Pneumonia	1	0
Employment History		
Length of employment intervals	4	3
Job classification	7	4
Organizational function	5	4
Job location	5	0
Cumulative production-heat dried sludge	3	0
Cumulative years of heat drying of sludge	3	0
Wastewater flow	3	0

*An additional 51 categories were examined using U.S. Vital Statistics.

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TABLE 100. COMPARISON OF SEX AND JOB CLASSIFICATIONS OF SAMPLE OF COHORT MEMBERS WITH KNOWN AND UNKNOWN VITAL STATUS

	Known Vital Status*	Unknown Vital Status*
Sex		
Male	238	59
Female	14	5
Unknown	3	3
	255	67
$X_2^2 = 3.613$	p = 0.16	
Job Classifications		
Maintenance Laborer A	40	12
Maintenance Laborer B	8	9
Fireman/Oiler	18	2
Operator	3	1
Engineer, Architects, and Laboratory Personnel	62	23
Trades	47	8
Other	44	11
Unknown	33	1
	255	67
$X_7^2 = 22.209$	p = 0.0023	

*Sample of about 10% of total members.

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TABLE 101. COMPARISON OF LENGTH OF EXPERIENCE AND YEAR OF BIRTH OF A SAMPLE* OF COHORT MEMBERS WITH KNOWN AND UNKNOWN VITAL STATUS

		Known Vital Status		Unknown Vital Status	
Length of Employment					
6 months-5 years		199		60	
5.1-10.0 years		94		27	
10.1-15.0 years		53		3	
15.1-20.0 years		45		1	
20.1-25.0 years		36		1	
25.1-30.0 years		40		0	
30 years		65		1	
	Total	532		93	
			$X^2_6 = 49.96$		$p = 0.0001$
Year of Birth					
After 1946		17		1	
1941-1945		26		8	
1936-1940		37		16	
1931-1935		36		7	
1926-1930		25		8	
1921-1925		32		12	
1916-1920		35		7	
1911-1915		38		12	
1906-1910		79		8	
Before 1906		209		15	
	Total	534		94	
			$X^1_9 = 38.05$		$p = 0.0001$

*Surnames beginning with letters A-F.

TABLE 102. AGE AT DEATH OF DECEASED COHORT MEMBERS

Age at Death, Years	White Males	White Females	Black Males
20-24	3	0	0
25-29	2	0	1
30-34	4	0	0
35-39	5	0	4
40-44	16	0	1
45-49	30	1	1
50-54	72	3	4
55-59	112	2	9
60-64	142	1	7
65-69	168	2	5
70-74	123	4	3
75-79	68	1	1
80-84	18	1	0
85-89	1	0	0
TOTAL	764	15	36

TABLE 103. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR ALL WORKERS FOR FIVE MAJOR CAUSES OF DEATHS (815 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	175	168.07
Cardiovascular disease	459	458.66
Diseases of the respiratory system	26	39.50
Accidents	25	30.99
All other causes	130	117.77

$X_4^2 = 7.418$ $P = 0.12$

TABLE 104. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR ALL WORKERS FOR TEN NEOPLASMS SUBGROUPINGS (815 WORKERS)

Cause of death	Observed	Expected	X_1^2	P
Pancreatic cancer	8	9.62	0.270	0.60
Leukemia	11	6.07	4.02	0.045
Buccal cavity neoplasms	3	5.90	1.436	0.23
Digestive tract neoplasms	47	49.77	0.164	0.69
Respiratory neoplasms	58	57.72	0.010	0.92
Breast neoplasms	2	0.78	1.910	0.17
Genital neoplasms	15	11.51	1.063	0.30
Urinary tract neoplasms	10	9.91	0.001	0.98
Lymph neoplasms	7	9.22	0.543	0.46
Unspecified neoplasms	22	16.67	1.740	0.19

TABLE 105. COMPARISONS OF OBSERVED AND EXPECTED NUMBER OF DEATHS USING U.S. VITAL STATISTICS ($P \leq .05$) WITH THOSE USING ILLINOIS VITAL STATISTICS

Cause of Death	U.S. Statistics*					Illinois Statistics				
	Observed (0)	Expected (E)	O/E	X_1^2	P	0	E	O/E	X_1^2	P
Esophageal cancer	8	3.79	2.11	4.69	.08**	8	4.23	1.89	3.37	0.13**
Leukemia	11	5.79	1.90	4.73	.03	11	6.07	1.81	4.02	.045
Pneumonia	7	15.85	0.44	5.05	.02	9	19.7	0.46	5.96	.02

*White males only
**Binomial

involving the various characteristics of employment history were made both for leukemia and pneumonia in addition to routine comparisons for the five major cause-of-death groups. Illinois Vital Statistics only are used in the rest of the statistical analysis.

Length of Employment

The total number, sex and race of the decedents in each length of employment category is presented in Table 106.

The observed and expected number of the major causes of death for the four length of employment categories are presented in Tables 107 through 110. There was no comparison for which the p-value was less than 0.20. However, for the 6 months to 10 years and 11 to 20 year worker groups the observed number of respiratory deaths was only about one-half of the expected. Such a relationship was not revealed for the two longer length of employment period groups.

Comparisons between observed and expected number of deaths from leukemia (Table 111) revealed a close to statistically significant difference ($p = .08$) excess of deaths in the 31 or more years of employment group. For deaths by pneumonia there were no statistically significant differences between observed and expected numbers.

Work Location

The total number, sex and race of the decedents in each work location category is presented in Table 112.

The observed and expected number of major causes of deaths for the five work location categories are presented in Tables 113 through 117. At the West-Southwest Wastewater Treatment Plant there were fewer than expected deaths from diseases of the respiratory system and from accidents ($p = 0.12$). In a comparison between observed and expected number of deaths from leukemia by job location (Table 118), the observed number of deaths was not statistically different than expected at any of the locations. For pneumonia deaths there were also no statistically significant differences between observed and expected number of deaths by work location.

Job Classification

The total number, sex and race of decedents in each of the job classification categories is presented in Table 119.

The observed and expected number of the major causes of death for the seven job classification categories are presented in Tables 120 - 126. No statistically significant results were revealed. For six of the seven job classification categories, deaths for diseases of the respiratory system were less than expected, the differences were most pronounced for Fireman-Oilers and Operating Personnel where the ratio of observed/expected was 0.5 and 0.4, respectively.

TABLE 106. NUMBER, SEX AND RACE OF DECEDENTS IN LENGTH OF EMPLOYMENT CATEGORIES

		Number of Decedents		
Length of employment	Total	White males	White females	Black males
6 mos. to 10 years	291	265	6	20
11 - 20 years	244	227	5	12
21 - 30 years	144	140	0	4
31 or more years	131	127	4	0
Totals	810	759	15	36

TABLE 107. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR WORKERS WITH 6 MONTHS TO 10 YEARS OF MSD EMPLOYMENT (291 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	60	58.68
Cardiovascular disease	152	156.93
Diseases of the respiratory system	7	13.35
Accidents	14	15.13
All other causes	58	46.92

$X_4^2 = 5.906$ $P = 0.20$

TABLE 108. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR WORKERS WITH 11-20 YEARS OF MSD EMPLOYMENT (244 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	53	50.53
Cardiovascular disease	145	138.09
Diseases of the respiratory system	6	11.93
Accidents	6	8.23
All other causes	34	35.22
	$X_4^2 = 4.065$	$P = 0.40$

TABLE 109. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR WORKERS WITH 21-30 YEARS OF MSD EMPLOYMENT (144 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	27	30.67
Cardiovascular disease	86	83.81
Diseases of the respiratory system	7	7.16
Accidents	4	3.95
All other causes	20	18.60
	$X_4^2 = 0.629$	$P = 0.93$

Table 110. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR WORKERS WITH 31 OR MORE YEARS OF MSD EMPLOYMENT (131 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	33	27.34
Cardiovascular disease	73	77.64
Diseases of the respiratory system	6	6.86
Accidents	1	2.91
All other causes	18	16.26
$X^2_4 = 2.997$		$P = 0.56$

TABLE 111. OBSERVED AND EXPECTED NUMBER OF DEATHS FROM LEUKEMIA FOR WORKERS DIVIDED ACCORDING TO LENGTH OF EMPLOYMENT

Length of employment	No. of workers	Observed no. of deaths (O)	Expected no. of deaths (E)	O/E	X^2_1	P
6 mos. to 10 yrs.	291	3	2.18	1.03	0.311	0.44
11-20 yrs.	244	3	1.82	1.23	0.777	0.63
21-30 yrs.	144	2	1.06	1.39	0.840	0.35
31 and more yrs.	131	3	0.98	2.29	4.195	0.08*

*Binomial

TABLE 112. NUMBER, SEX AND RACE OF DECEDENTS IN SPECIFIC WORK LOCATION CATEGORIES

		Number of Decedents		
Job location category	Total	White males	White females	Black males
West-Southwest treatment plant	339	325	1	13
Calumet treatment plant	77	69	0	8
Northside treatment plant	83	83	0	0
Downtown	175	159	11	5
Variable, indeterminant and other	141	128	3	10
Totals	815	764	15	36

TABLE 113. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR WEST-SOUTHWEST WASTEWATER TREATMENT PLANT WORKERS (339 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	74	69.72
Cardiovascular disease	189	187.33
Diseases of the respiratory system	9	15.78
Accidents	8	14.71
All other causes	59	51.08
$X_4^2 = 7.487$		P = 0.12

TABLE 114. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR CALUMET WASTEWATER TREATMENT PLANT WORKERS (77 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	18	15.57
Cardiovascular disease	43	43.22
Diseases of the respiratory system	3	3.89
Accidents	2	2.72
All other causes	11	11.60
$X_4^2 = 0.806$	P = 0.90	

TABLE 115. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR NORTHSIDE WASTEWATER TREATMENT PLANT WORKERS (83 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	17	17.60
Cardiovascular disease	41	46.35
Diseases of the respiratory system	3	3.97
Accidents	5	3.02
All other causes	17	12.06
$X_4^2 = 4.197$	P = 0.38	

TABLE 116. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR WORKERS AT DOWNTOWN CHICAGO LOCATION (175 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	37	35.63
Cardiovascular disease	104	101.70
Diseases of the respiratory system	6	8.91
Accidents	7	5.85
All other causes	21	22.91

$X_4^2 = 1.433$ $p = 0.92$

TABLE 117. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR WORKERS AT VARIABLE, OTHER AND INDETERMINANT LOCATIONS (141 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	29	29.61
Cardiovascular disease	82	79.32
Diseases of the respiratory system	5	6.90
Accidents	3	4.86
All other causes	22	20.29

$X_4^2 = 1.482$ $p = 0.83$

TABLE 118. OBSERVED AND EXPECTED NUMBER OF DEATHS FROM LEUKEMIA FOR WORKERS ACCORDING TO WORK LOCATION

Job location	No. of workers	Observed no. of deaths	Expected no. of deaths	χ^2_1	P
West-Southwest	339	4	2.51	.880	0.35
Calumet	77	2	0.56	3.716	0.21*
Northside	83	2	0.61	3.268	0.24*
Downtown	175	1	1.33	.109	0.80
Variable, other and indeterminant	141	2	1.05	.866	0.92

*Binomial

TABLE 119. NUMBER, SEX AND RACE OF DECEDENTS IN THE SEVEN JOB CLASSIFICATION CATEGORIES

		Number of Decedents		
Job category	Total	White males	White females	Black males
Maintenance laborer A	152	137	0	15
Maintenance laborer B	31	27	0	4
Fireman-oiler	83	82	0	1
Operating personnel	112	105	0	7
Engineers, architects and lab personnel	200	191	1	8
Tradesmen	155	155	0	0
Other	82	67	14	1
Totals	815	764	15	36

TABLE 120. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR MAINTENANCE LABORER A WORKERS (152 DECEDENTS)

Cause of death	Observed	Expected
Neoplasms, all sites	35	30.51
Cardiovascular disease	83	84.31
Diseases of the respiratory system	5	7.34
Accidents	5	6.45
All other causes	24	23.39
$X_4^2 = 1.766$	$p = 0.80$	

TABLE 121. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR MAINTENANCE LABORER B WORKERS (31 DECEDENTS)

Cause of death	Observed	Expected
Neoplasms, all sites	9	6.26
Cardiovascular disease	15	17.89
Diseases of the respiratory system	0	1.56
Accidents	1	1.04
All other causes	6	4.24
$X_4^2 = 4.043$	$p = 0.40$	

TABLE 122. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR FIREMAN-OILERS (83 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	12	17.09
Cardiovascular disease	53	46.92
Diseases of the respiratory system	2	3.86
Accidents	1	3.28
All other causes	15	11.86
$X_4^2 = 5.605$	$p = 0.20$	

TABLE 123. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR OPERATING PERSONNEL (112 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	17	23.56
Cardiovascular disease	70	62.34
Diseases of the respiratory system	2	5.33
Accidents	5	3.93
All other causes	18	16.84
	$X_4^2 = 5.219$	$p = 0.27$

TABLE 124. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR ENGINEERS, ARCHITECTS AND LABORATORY PERSONNEL (200 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	45	41.62
Cardiovascular disease	109	111.77
Diseases of the respiratory system	6	9.80
Accidents	7	8.25
All other causes	33	28.60
	$X_4^2 = 2.672$	$p = 0.65$

TABLE 125. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR TRADESMEN (155 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	35	31.41
Cardiovascular disease	86	89.38
Diseases of the respiratory system	7	7.84
Accidents	4	5.31
All other causes	23	21.06
$X_4^2 = 1.130$	$p = 0.88$	

TABLE 126. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR OTHER PERSONNEL (82 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	22	17.63
Cardiovascular disease	43	45.72
Diseases of the respiratory system	4	3.71
Accidents	2	2.88
All other causes	11	12.06
$X_4^2 = 1.64$	$p = 0.80$	

In a comparison of observed and expected leukemia deaths by job classification (Table 127) the observed number of deaths was greater than the expected number for six of the seven classes and was close to statistically significant ($p = .09$) for one of these, the "Other" class. For pneumonia there were significantly fewer than expected number of deaths for tradesmen ($p = 0.04$, Table 128).

Organizational Function

The total number, sex and race of decedents in each of the organizational function categories is presented in Table 129.

Comparisons of the observed and expected number deaths for the five organizational function groups, presented in Tables 130 - 134, revealed that for Engineering workers, neoplasms and accidents were greater than expected and diseases of respiratory system and all other causes were less than expected Table 131, $p = .07$).

For leukemia deaths according to organization function (Table 135) a statistically significant excess of observed over expected number of deaths was found for Maintenance, Security and Safety ($p = .03$) and for Operations the difference was close to significance ($p = .08$). There were significantly fewer than expected pneumonia deaths ($p = 0.02$) for the maintenance, security and safety function job category (Table 136).

Heat Dried Sludge and Wastewater Flow

The total number, sex and race of decedents for the heat dried sludge (cumulative production and years) and wastewater flow categories are presented in Table 137.

Observed and expected number of cases for each of the major causes of death and for leukemia, for the three heat dried sludge cumulative production categories are presented in Tables 138 and 139, respectively. No statistically significant differences ($p \leq 0.05$) for the major causes of death or leukemia were observed. For pneumonia, there were no significant differences between the dried sludge production categories.

Observed and expected number of cases for each of the major causes of death and for leukemia for the three categories of years of heat drying of sludge are presented in Tables 140 and 141, respectively. No statistically significant differences ($p \leq 0.05$) for the major causes of death or leukemia were observed. However, for pneumonia, there were no significant differences between the sludge years categories.

There were no differences between observed and expected number of cases according to wastewater flow category for each of the major causes of death and for leukemia (Tables 142 and 143, respectively). For pneumonia, there were also no significant differences.

TABLE 127. OBSERVED AND EXPECTED LEUKEMIA DEATHS BY JOB CLASSIFICATION

classification	No. of workers	Observed no. of deaths	Expected no. of deaths	X^2_1	P
Maint. Lab. A	152	2	1.08	.801	.37
Maint. Lab. B	31	1	.21	.213	.65
Fireman-Oiler	83	1	.65	.192	.64
Operating personnel	112	0	.79	.796	.37
Engineers, architects and lab personnel	200	3	1.54	1.395	.25
Tradesmen	155	2	1.17	.593	.45
Other	82	2	.63	3.002	.09

TABLE 128. OBSERVED AND EXPECTED NUMBER OF DEATHS FROM PNEUMONIA FOR WORKERS DIVIDED ACCORDING TO JOB CLASSIFICATION

Job Classification	No. of Workers	Observed No. of Deaths	Expected No. of Deaths	X^2_1	p
Maintenance Laborer A	152	5	3.88	0.332	0.55
Maintenance Laborer B	31	0	0.84	0.864	0.35
Fireman/Oiler	83	0	1.85	1.892	0.20
Operating Personnel	112	0	2.67	2.735	0.10
Engineers, architects and lab personnel	200	2	4.76	1.639	0.20
Tradesmen	155	0	3.75	3.875	0.04*
Other	82	2	1.88	0.007	0.95

*Binomial

TABLE 129. NUMBER, SEX AND RACE OF DECEDENTS IN THE ORGANIZATIONAL FUNCTION CATEGORIES

Organizational function	Total	Number of Decedents White males	White females	Black males
Research and development	18	15	1	2
Engineering	115	111	0	4
Maintenance, security and safety	209	193	1	15
Treatment operations	309	298	0	11
Administrative (including purchasing, personnel, law and finance)	164	147	13	4
Totals	815	764	15	36

TABLE 130. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR RESEARCH AND DEVELOPMENT WORKERS (18 DECEDENTS)

Cause of death	Observed	Expected
Neoplasms, all sites	2	3.69
Cardiovascular disease	7	8.61
Diseases of the respiratory system	1	0.81
Accidents	1	1.40
All other causes	7	3.49

$X_4^2 = 4.667$ $p = 0.35$

TABLE 131. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR ENGINEERING WORKERS (115 DECEDENTS)

Cause of death	Observed	Expected
Neoplasms, all sites	31	24.06
Cardiovascular disease	64	64.13
Diseases of the respiratory system	2	5.63
Accidents	8	4.88
All other causes	10	16.30

$\chi^2_4 = 8.784$ $p = .07$

TABLE 132. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR MAINTENANCE, SECURITY AND SAFETY PERSONNEL (209 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	49	43.68
Cardiovascular disease	116	116.58
Diseases of the respiratory system	6	10.07
Accidents	2	7.54
All other causes	36	31.16

$\chi^2_4 = 7.118$ $p = 0.14$

TABLE 133. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR OPERATING PERSONNEL (309 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	63	63.24
Cardiovascular disease	171	174.03
Diseases of the respiratory system	11	14.76
Accidents	11	12.15
All other causes	53	44.82
$X_4^2 = 2.613$		$p = 0.77$

TABLE 134. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR ADMINISTRATIVE PERSONNEL (164 WORKERS)

Cause of death	Observed	Expected
Neoplasms, all sites	30	33.47
Cardiovascular disease	101	95.10
Diseases of the respiratory system	6	8.18
Accidents	3	5.09
All other causes	24	22.16
$X_4^2 = 2.318$		$p = 0.80$

TABLE 135. OBSERVED AND EXPECTED NUMBER OF LEUKEMIA DEATHS FOR WORKERS DIVIDED ACCORDING TO ORGANIZATIONAL FUNCTION

Organizational function	No. of workers	Observed no. of deaths	Expected no. of deaths	χ^2_1	P
Research and development	18	0	0.15	.146	.70
Engineering	115	0	.91	.917	.34
Maintenance, security and safety	209	4	1.51	4.136	.03*
Operations	309	5	2.27	3.307	.08
Administrative	164	2	1.24	.469	.49

*0.038 (binomial)

TABLE 136. OBSERVED AND EXPECTED PNEUMONIA DEATHS ACCORDING TO ORGANIZATIONAL FUNCTION

Organizational Function	No. of Workers	Observed No. of Deaths	Expected No. of Deaths	χ^2_1	p
Research and Development	18	1	0.44	0.718	0.40
Engineering	115	0	2.70	2.765	0.10
Maintenance Security and Safety	209	0	5.00	5.123	0.02
Treatment Operation	309	6	7.40	0.271	0.60
Administrative (including Purchasing, Personnel, Law and Finance)	164	2	4.14	1.134	0.30

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TABLE 137. NUMBER, SEX, AND RACE OF DECEDENTS IN HEAT DRIED SLUDGE AND WASTEWATER FLOW CATEGORIES

		Number of Decedents		
Category	Total	White Males	White Females	Black Males
Heat dried sludge production*				
0 tons/day	257	239	11	7
1-5000 tons/day	250	235	1	14
more than 5000 tons/day	167	162	0	5
	674	636	12	26
Years of heat dried sludge production				
0 years	257	239	11	7
1-14 years	213	199	1	13
15 and more years	204	198	0	6
	674	636	12	26
Wastewater flow, MGD**				
0-4,000 MGD	333	305	11	17
4001-12,000 MGD	176	170	1	5
more than 12,000 MGD	165	161	0	4
	674	636	12	26

*Total of yearly daily average production
**Total of yearly average flow in MGD (millions of gallons per day)

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TABLE 138. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR THREE CATEGORIES BASED ON CUMULATIVE YEARLY DAILY AVERAGE PRODUCTION OF HEAT DRIED SLUDGE AT LOCATION OF EMPLOYMENT

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	Sludge Category 1 0 tons/day		Sludge Category 2 1-5000 tons/day		Sludge Category 3 more than 5000 tons/day	
Cause of Death	Observed	Expected	Observed	Expected	Observed	Expected
Neoplasms, all sites	53	52.78	59	49.99	34	35.76
Cardiovascular diseases	144	147.20	134	137.14	99	94.87
Diseases of the respiratory system	9	12.85	5	11.68	7	8.03
Accidents	12	8.97	9	11.93	1	5.25
All other causes	39	35.20	43	39.26	26	23.08
Total Number	257		250		167	
	$X_4^2 = 2.66$		$X_4^2 = 6.59$		$X_4^2 = 4.21$	
	p = 0.61		p = 0.25		p = 0.38	

TABLE 139. OBSERVED AND EXPECTED NUMBER OF LEUKEMIA DEATHS FOR THREE CATEGORIES BASED ON CUMULATIVE YEARLY DAILY AVERAGE PRODUCTION OF HEAT DRIED SLUDGE AT LOCATION OF EMPLOYMENT

Heat Dried Sludge Category	No. of Workers	Observed No. Deaths	Expected No. Deaths	X_1^2	p
0 tons/day	257	3	1.93	0.60	0.44
1-5000 tons/day	250	4	1.85	2.52	0.12
more than 5000 tons/day	167	2	1.24	0.47	0.48

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TABLE 140. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR THREE CATEGORIES OF TOTAL NUMBERS OF YEARS EMPLOYED AT A FACILITY WHERE SLUDGE HEAT DRYING WAS BEING PRACTICED

	0 Years		1-14 Years		15 or More Years	
Cause of Death	Observed	Expected	Observed	Expected	Observed	Expected
Neoplasms	53	52.78	47	42.60	46	43.14
Cardiovascular diseases	144	147.10	116	114.82	117	117.19
Diseases of the respiratory system	9	12.85	5	9.73	7	9.98
Accidents	12	8.97	9	11.17	1	6.01
All other causes	39	35.20	36	34.67	33	27.68
Total Number	257		213		204	
	$X^2_4 = 2.66$		$X^2_4 = 3.24$		$X^2_4 = 6.28$	
	$p = 0.61$		$p = 0.52$		$p = 0.14$	

TABLE 141. OBSERVED AND EXPECTED NUMBER OF LEUKEMIA DEATHS FOR THREE CATEGORIES OF TOTAL NUMBER OF YEARS EMPLOYED AT A FACILITY WHERE SLUDGE HEAT DRYING WAS BEING PRACTICED

Heat Dried Sludge Years Category	No. of Workers	Observed No. Deaths	Expected No. Deaths	X^2_1	p
0	257	3	1.93	0.60	0.44
1-14	213	3	1.57	1.31	0.25
15 or more	204	3	1.53	1.42	0.23
Total	674				

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TABLE 142. OBSERVED AND EXPECTED NUMBER OF DEATHS FOR THREE CATEGORIES OF WASTEWATER FLOW BASED ON CUMULATIVE YEARLY DAILY AVERAGE FLOW OF WASTEWATER AT LOCATION OF EMPLOYMENT

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	Flow Category					
	0-4000 MGD		4001-12,000 MGD		More than 12,000 MGD	
Cause of Death	Observed	Expected	Observed	Expected	Observed	Expected
Neoplasms, all sites	77	67.09	33	36.46	36	34.97
Cardiovascular diseases	180	187.20	104	97.66	93	94.35
Diseases of the respiratory system	12	16.43	3	8.11	6	8.03
Accidents	14	13.45	7	7.63	1	5.07
All other causes	50	48.83	29	26.14	29	22.57
Total	333		176		165	
	$\chi^2_4 = 2.75$		$\chi^2_4 = 4.32$		$\chi^2_4 = 5.61$	
	$p = 0.60$		$p = 0.36$		$p = 0.22$	

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TABLE 143. OBSERVED AND EXPECTED NUMBER OF LEUKEMIA DEATHS FOR THE THREE CATEGORIES OF CUMULATIVE YEARLY DAILY AVERAGE WASTEWATER FLOW AT LOCATION OF EMPLOYMENT

Cumulative Yearly Daily Average Flow	No. of Workers	Observed No. Deaths	Expected No. Deaths	χ^2_1	p
0-4000 MGD*	333	5	2.50	2.52	0.12
4001-12,000 MGD	176	3	1.29	2.283	0.15
More than 12,000 MGD	165	1	1.23	0.41	0.51

*MGD = millions of gallons per day

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Leukemia

A summary of employment history and demographic data for the 11 workers whose underlying cause of death was leukemia is presented in Table 144. The average age at time of hiring by MSD was 38 years (range 25-63 years), the average age at death was 67 years (range 48-77 years) and the average length of employment at MSD was 21 years (range 4-40 years). All were white males. Three of the eleven were born outside the U.S.A., one each in Italy, Ireland and Russia. Three had service in World War I; two had service in World War II, the MSD employment of one being interrupted for more than two years. A number of the 11 workers with leukemia didn't spend the majority of their working careers with MSD, and presumably worked in other industries. Workers in other industries and indeed non-workers are included in the reference population (whole population of Illinois) with which the MSD workers were compared. Therefore, the fact that workers didn't spend their entire working career with MSD would tend to dilute any effects of MSD employment.

Of the eleven leukemia cases, six were of the myelocytic type, two were lymphocytic and three were unspecified types. Chronic lymphocytic leukemia is associated with aging; one of the lymphocytic cases was specified as "chronic lymphocytic leukemia" and the other only as "lymphocytic leukemia." Autopsies were performed in three instances, all of which were of the myelocytic type. It has been well-established that radiation exposure can be a cause of leukemia, although not chronic lymphocytic leukemia (68). Occupational exposures to some chemicals has also been linked to leukemia (69). In some animal species it has been established that viruses can be the causative agent of leukemia and there has been the suggestion that viruses may play a role in the development of leukemia in humans (70). These results should be followed-up by additional studies of MSD employees and of employees at other wastewater collection and treatment systems.

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Pneumonia

The meaning of the fewer than expected number of pneumonia deaths is not clear. The finding of fewer than expected number of deaths among the maintenance, security and safety workers is consistent with the finding of a fewer than expected number of deaths among tradesmen since, as the categories were defined, tradesmen perform maintenance functions.

SUMMARY AND CONCLUSIONS

For the five major cause of death groupings and the various employment history groupings--length of employment, job location, job classification, organizational function, heat dried sludge factors and wastewater flow--there were no comparisons for which $p < 0.05$. However there were two comparisons at $p = 0.12$ (all workers and West-Southwest plant workers) and one at $p = 0.07$ (Engineering Organizational Function) where observed number of neoplasm deaths and "all other causes" deaths were greater than expected and deaths from respiratory system diseases were less than expected. For two of these three comparisons accidental deaths were less than expected. No excess of pancreatic cancer deaths was observed in contrast to the finding of an excess in Copenhagen sewer workers (64). For all 815 decedents as a group there were more leukemia

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TABLE 144. EMPLOYMENT HISTORY AND DEMOGRAPHIC DATA OF WORKERS WHOSE UNDERLYING CAUSE OF DEATH WAS LEUKEMIA

Worker number	Year of birth	Year of death	Years at MSD	Job title	Organization	Job location
1	1900	1965	1925-65	Operating engineer	Treatment operations	Calumet
2	1896	1973	1949-63	Parking lot attendant	Security	Indeterminant
3	1909	1964	1955-64	Electrical mechanic	Maintenance	Northside
4	1922	1970	1959-70	Maintenance laborer B	Maintenance	West-Southwest
5	1896	1973	1938-62	Architectural ironworker	Maintenance	Indeterminant
6	1901	1968	1964-68	Maintenance laborer A	Operations	West-Southwest
7	1896	1970	1954-60	Maintenance laborer A	Operations	West-Southwest
8	1905	1975	1940-72	Operating engineer	Operations	West-Southwest
9	1913	1976	1941-76	Fireman-oiler	Operations	Northside
10	1897	1975	1923-63	Engineer of treatment plant operations	Administrative	Calumet
11	1897	1963	1948-63	Clerk	Administrative	Downtown

Three workers were born outside the U.S.A.: No. 2 (Italy), No. 8 (Ireland) and No. 9 (Russia). Type of leukemia was myelocytic for Nos. 1,3,4,5,7 and 8, lymphocytic for 2 and 10 and unspecified for 6,9 and 11. All workers were white males. Three had WWI service (2,5,10), two WWII (4,8).

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deaths observed than expected (11 and 6.1, respectively), (p = 0.045) and fewer pneumonia deaths observed than expected (9 and 19.7, respectively) (p = 0.02). Examining leukemia deaths according to employment history, revealed a close to statistically significant higher number of observed than expected leukemia deaths for workers with 31 or more years of MSD employment (p = 0.08), and for workers whose organizational function was maintenance, security and safety (p = 0.04). The observed number of leukemia deaths was also close to significantly significant for workers in the "other" job classification (p = 0.09) and for workers whose organizational function was operations (p = 0.08). Based on U.S. Vital Statistics there was a close to significant (p = 0.08) excess in cancer of the esophagus, 8 observed and 3.8 expected; however this difference had slightly lower significant value (p = 0.13) using Illinois Statistics. Additional study of MSD workers and of workers in other wastewater treatment systems is warranted to determine if these findings can be repeated. Efforts should continue to determine the vital status of cohort members for whom it has not been determined, more than 90% of whom are estimated to have worked for MSD for less than 10 years.

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SECTION 7

CHEMICAL ANALYTICAL ANALYSES OF SELECTED URINE AND SERUM FROM PREVIOUS HARDEMAN COUNTY TOXIC DUMP STUDY

In Hardeman County, TN leachate from a pesticide waste dump had contaminated the water supply wells of a small rural community (Table 145). The exposed population was found to have evidence of liver insult as detected by tests of liver function and by a physical examination which revealed enlarged livers in some of the residents (6). An intermediate-exposed group was also identified who were individuals whose wells were contaminated to a lower degree or who had only intermittent contact with the contaminated well water. In our previous study of the exposed and control populations near the Hardeman County toxic waste dump site, the focus of the chemical analyses was on the analysis of urine for hexachlorocyclopentadiene (Hex) and hexachlorobicycloheptadiene (Hex-BCH) (6). These two compounds had also been identified in urine from wastewater treatment plant workers in Memphis, TN (8) who had been exposed to some of the same toxic wastes which were in the influent wastewater stream. Additional chemical analyses of urine of the Hardeman County study participants was also performed at that time for carbon tetrachloride, the most abundant contaminant detected in the drinking water wells. Nine urine samples from individuals with high exposure were selected for analyses. Carbon tetrachloride was not detected in any of these samples. This was consistent with earlier literature reports that showed that carbon tetrachloride administered to mammals was largely excreted through the lungs, that only a small fraction of absorbed material was metabolized and that only a small portion of the CCl_4 was excreted as the parent compound in the urine (71,72). The primary metabolites were thought to include chloroform, hexachloroethane and carbon dioxide. The limited biological monitoring that had been performed on urine and serum of Hardeman County residents was inadequate to document exposure.

During the course of this cooperative agreement two additional chemical analyses involving biological specimens previously collected from Hardeman County study participants were undertaken: (1) Analyses of 50 serum specimens for volatile purgeable halogenated hydrocarbons under the auspices of another U.S. EPA Cooperative Agreement by Dr. Anita Peoples at the University of Miami, Department of Epidemiology and Public Health, and (2) thioether analyses of 20 urine specimens from Hardeman County and 20 from a related study in Memphis, TN, by a doctoral candidate in the Department of Environmental Health at the University of Cincinnati. Forty serum specimens from 20 exposed and intermediate-exposed individuals in Hardeman County and single specimens from each of 10 controls of similar age and sex distribution were selected for volatile organic analysis. The Hardeman County study urine samples analyzed were selected from specimens from these same individuals, when available, with 10

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TABLE 145. CONCENTRATION OF SELECTED VOLATILE ORGANIC CHEMICALS IN WATER SUPPLIES OF HARDEMAN COUNTY STUDY GROUPS, $\mu g/L$

	Exposed		Intermediate-Exposed		Controls	
	Range	Median	Range	Median	Range	Median
Carbon tetrachloride	61-18,700	1,500	25-96	43	0.3-1.1	<0.3
Chloroform	2.1-1890	140	<2		<2	
Chlorobenzene	trace-41	5.0	<0.1-trace		<0.1	
Tetrachloroethylene	trace-2,405	3.5	<0.2-66	<0.2	<0.2-1.4	<0.2
Hexachlorobicycloheptadiene	<0.1-2.2	0.2	<0.1		<0.1	

(Table based on U.S. Environmental Protection Agency, State of Tennessee and University of Cincinnati data.)

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from the exposed and intermediate-exposed group and 10 from the controls. The Memphis urine specimens for thioether determinations were selected from 10 individuals from the North Plant for whom in a portion of the urine specimens either Hex or Hex-BCH had been detected. The specimens selected from the second Memphis wastewater treatment plant, the South Plant, were from workers with similar age, race and sex and in which these two compounds had not been detected.

A method for the analysis of human serum for ten volatile purgeable halogenated hydrocarbons has been developed at the University of Miami and was used to analyze specimens from persons consuming chlorinated drinking water containing chloroform in excess of 300 µg/l (73). Since four of the compounds detectible by this method were present in the contaminated well water in Hardeman County (chloroform, carbon tetrachloride, tetrachloroethylene and chlorobenzene) an attempt was made to apply it to frozen sera available from study participants.

Analysis of urine for thioethers has been proposed as a possible biological measure of exposure to chemical waste mixtures since a first step in the catabolism of many xenobiotics involves action by microsomal enzymes and leads to the excretion of urinary thioethers and other substances. The amount of thioether excretion is indirectly related to the amount of hepatic labile and non-labile glutathione pool mobilization in response to formation or deposition of electrophilic compounds. A number of chemical exposures induce thioether formation (74) including aromatics, unsaturated aliphatics, esters and epoxides (75) and also ethanol, acetaldehyde, formaldehyde (76), styrene oxide (77), carbon disulfide (74), and methyl chloride (78). Many mutagens and carcinogens also stimulate thioether excretion. Increased thioethers were found in the urine of workers employed in a rubber plant (79), a chemical plant (80), and in a chemical waste incinerator facility (81). The excretion of thioethers is also influenced by parameters other than exposures to xenobiotics which produce electrophilic compounds, e.g., cigarette smoking, drug taking, alcohol consumption, dietary composition, medication usage, fasting intervals, and incidence of disease (74,76,82). Many base labile compounds like thiazolidines or dithiazolidones, may also be analyzed by the thioether test (74,76).

METHODS

Volatile Hydrocarbons

A purge/trap/desorb procedure was used to prepare the serum samples for analysis on a gas chromatograph equipped with a Hall electrolytic conductivity detector operated in the halide specific mode (73). An N-octane column was used for the first 23 samples and an SP-1000 column for the remaining 27 samples. The first column could not distinguish between 1,1,1-trichloroethane or trichloroethylene (TCE) nor between tetrachloroethylene or bromodichloromethane while the latter column could. The specimens chosen for analysis included some from each of the three groups in the Hardeman County study: exposed, intermediate-exposed and control, although most specimens were from the exposed group. At least two specimens, generally collected two months apart, were analyzed for most of the exposed participants. Since exposed

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participants had already stopped drinking the contaminated water about six months prior to the study, the analyses of multiple samples would provide some information regarding the length of time excretion of the compounds persisted. The intermediate-exposed group members whose specimens were analyzed were still using contaminated water (Table 151) at the time of serum collection. Sera had been stored at -20°C.

Thioethers

Thioether determinations quantitated total alkaline hydrolysable S compounds after an initial ethyl acetate extract of the urine in the manner of Van Doorn et al. (74,83). Five mL of the urine was extracted with ethyl acetate (2 x 5 mL), the amalgamated extract evaporated, the residue dissolved in 2 mL of distilled water. To 1 mL of this solution was added 0.5 mL N NaOH, and the solution heated at 50°C for half an hour. After cooling, 0.5 mL 4 N HCl was added, 200 μL of this neutralized solution was reacted with the Ellman reagent (2.8 mL) as set out in Ellman (83). The sulfhydryl content was then calculated. Wastes from a pesticide manufacturing company which produced chlordane, endrine and hexachlorocyclopentadiene flowed to the Memphis North wastewater treatment plant and had previously been dumped at the Hardeman County toxic waste site. Eight of the Hardeman County urine specimens were from the exposed group, two were from members of the intermediate-exposed group who were still using the contaminated water at the time of collection and 10 were from the control group.

RESULTS AND DISCUSSION

Volatile Hydrocarbons. A tabulation of all results of the chemical analyses of the 50 serum specimens is presented in Table 146 along with date of collection, sex, and month/year of birth Chloroform was detected in all samples and there were no statistical differences between the groups. No detectible amounts were found of the following compounds: carbon tetrachloride, 1,2 dichloroethane, chlorobenzene and vinylidene chloride. For sixteen individuals in the exposed group both a November 1978 and a later specimen (usually January 1979) were analyzed. The first and second specimens are compared in Table 147. Although somewhat more November 1978 specimens were positive for the compound pairs (1,1,1-trichloroethane or trichloroethylene and tetrachloroethylene or bromodichloromethane) than were the later specimens, the results were not significantly different for each compound pair. For an additional statistical analyses, the results from the first specimen analyzed for each individual were combined for the exposed and intermediate-exposed group, because of the small number of specimens in group 2, and compared with the results from the first specimens analyzed from the control group (Table 148). Differences were not detected for either compound pair analyzed.

Thioethers. Results of the urine thioether determinations for the Memphis wastewater treatment plant workers are presented in Table 149 along with age, race, smoking history, job title and previously-determined concentrations of hexachlorocyclopentadiene (Hex) and hexachlorobicycloheptadiene (Hex-BCH)(8). The thioether levels for two workers at the North Plant were greater than 5.9 m mole SH/mole creatinine, the postulated critical value (74), with another one

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TABLE 146. RESULTS OF SERUM ANALYSES OF SELECTED HARDEMAN COUNTY STUDY PARTICIPANTS FOR VOLATILE PURGEABLE HALOGENATED HYDROCARBONS

				Concentration,* μg/L				
Group	Sex	Birth Mo/Yr.	Sample Date	Chloroform	1,1,1-Trichloro-ethane	Trichloro-ethylene	Tetrachloro-ethylene	Bromodi-chloromethane
1	M	4/45	11/78	21		(2)a		(2)b
			1/79	30				
			3/79	8		(6)a		(11)b
1	F	3/65	11/78	38		(1)a		
			1/79	96		(6)a		
1	F	10/69	11/78	28	Trace		Trace	
			1/79	100			Trace	Trace
1	M	5/68	11/78	78				
			1/79	73				
1	M	10/50	11/78	24		(3)a		(2)b
			1/79	16				
1	F	6/52	1/79	12		1	2	
1	M	9/72	11/78	22				
			1/79	32				
			3/79	12				
1	M	2/49	11/78	9			Trace	
			1/79	12				
1	F	4/49	11/78	8				
			1/79	11				
1	F	1/70	11/78	20				
			1/79	16	35		2	
1	F	5/72	11/78	16				
			3/79	7				
1	M	1/48	11/78	10				
			1/79	8				
1	F	10/51	11/78	27			2	
			1/79	5				
1	M	4/51	11/78	26		(2)a		(3)b
			1/79	8				
1	M	5/18	11/78	15			3	
			1/79	15			8	
1	F	11/52	11/78	29		(2)a		(3)b

(continued)

TABLE 146 (continued)

Group	Sex	Birth Mo/Yr.	Sample Date	Chloroform	Concentration,* µg/L 1,1,1-Trichloroethane	Trichloroethylene	Tetrachloroethylene	Bromodichloromethane
1	F	9/45	11/78	10				
			1/79	8				
1	M	4/70	11/78	75				
			1/79	50				
2	F	6/27	1/79	5				
			3/79	6				
2	M	10/75	1/79	26	2		2	
			3/79			1	3	
3	M	2/48	1/79	50				
3	M	6/66	1/79	16				
3	F	3/69	1/79	17				
3	F	8/50	1/79	37				
3	F	8/46	1/79	16				
3	M	3/50	1/79	20	3			
3	M	2/17	1/79	5				
3	F	9/68	1/79	9	1	6	2	
3	F	2/74	1/79	11		5		
3	F	12/25	1/79	7		1	3	

*Blank value in table signifies below detection level (<1 ug/L).

[a] Column unable to distinguish between 1,1,1-trichloroethane and trichloroethylene.

[b] Column unable to distinguish between tetrachloroethylene and bromodichloromethane.

[c] Public water supply.

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TABLE 147. COMPARISON OF RESULTS OF ANALYSIS OF NOVEMBER 1978 AND JANUARY 1979 SERUM SPECIMENS FROM EXPOSED GROUP

Date	Compound	Number of specimens below detection limit	Number of specimens at or above detection limit
November 1978	1,1,1-Trichloroethane[a]	11	5
January 1979	1,1,1-Trichloroethane[a]	14	2
	$X^2 = 0.73$	$p = 0.39$	
November 1978	Tetrachloroethylene[c]	9	7
January 1979[b]	Tetrachloroethylene[c]	13	3
	$X^2 = 1.31$	$p = 0.25$	

[a] Compound could also be trichloroethylene since for some analyses the column used couldn't distinguish between these two compounds.

[b] March 1979 for 1 specimen.

[c] Compound could also be bromodichloromethane since for some analyses the column used couldn't distinguish between these two compounds.

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TABLE 148. COMPARISON OF RESULTS OF ANALYSIS OF FIRST SPECIMENS ANALYZED FROM COMBINED EXPOSED-INTERMEDIATE EXPOSED GROUP AND CONTROL GROUP

		Number of specimens	
Group	Compound	below detection limit	at or above detection limit
1 & 2	1,1,1-Trichloroethane[a]	11	9
3	1,1,1-Trichloroethane[a]	6	4
		$X^2 = 0.02$	$p = 0.90$
1 & 2	Tetrachloroethylene[b]	10	10
3	Tetrachloroethylene[b]	8	2
		$X^2 = 1.41$	$p = 0.24$

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[a] Compound could also be trichloroethylene since for some analyses column used couldn't distinguish between these two compounds.

[b] Compound could also be bromodichloromethane since for some analyses column used couldn't distinguish between these two compounds.

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TABLE 149. THIOETHER LEVELS IN MEMPHIS WASTEWATER TREATMENT PLANT WORKERS EXPOSED TO PESTICIDE WASTES

Worker	Age (yrs.)	Race	Smoking history*	Job title	Thioether concentrations m moles/mole creatinine	Previous results-ng/mL Hex	Previous results-ng/mL Hex-BCH
North Plant							
1	57	White	NS	Supervisor	1.32	b.d.	10.3
2	22	White	S	Mechanical Operator	1.72	b.d.	5.0
3	32	Black	NS	Wastewater Operator	2.17	b.d.	7.6
4	29	White	S	Storekeeper	27.9[a]	b.d.	6.3
5	39	Black	S	Mechanical Operator	5.0	b.d.	2.0
6	21	White	NS	Mechanical Operator	4.15	b.d.	2.3
7	44	Black		Mechanical Operator	6.47[a]	2.9	b.d.
8	23	White	NS	Mechanical Operator	2.73	b.d.	2.9
9	31	White		Maintenance Mechanic	3.02	2.2	4.9
10	58	White		Engineer	2.43	b.d.	3.9
South Plant							
11	26	White	NS	Maintenance Mechanic	2.39	b.d.	b.d.
12	28	White	FS	Mechanical Operator	3.66	b.d.	b.d.
13	30	White	FS	Wastewater Operator	.86	b.d.	b.d.
14	34	Black		Maintenance Helper	b.d.	b.d.	b.d.
15	28	White	S	Laboratory Chemist	b.d.	b.d.	b.d.
16	30	Black	S	Mechanical Operator	2.72	b.d.	b.d.
17	45	White		Wastewater Operator	2.01	b.d.	b.d.
18	27	White		Wastewater Operator	1.32	b.d.	b.d.
19	28	White	NS	Wastewater Operator	3.70	b.d.	b.d.
20	25	White	NS	Wastewater Operator	1.74	b.d.	b.d.

*NS = Non-smoker, S = Smoker, FS = Former Smoker; blank signifies no information.

b.d. = below detection (0.2 m mole/mole creatinine for thioether, 0.8 ng/L for Hex and 0.3 ng/L for Hex-BCH).

All workers are male except for no. 15.

[a] >5.4 m mole/mole creatinine.

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at 5.0. There were four workers at the North Plant whose values were greater than that of the worker with the highest thioether value at the South Plant, i.e., 3.70 m mole/mole creatinine.

Results for the Hardeman County populations, all of whom were white, are presented in Table 150.

Memphis and Hardeman County data were analyzed by comparing the number below and above the median values which were 2.41 m mole SH/mole creatinine in Memphis and 3.62 m mole SH/mole creatinine in Hardeman County (Table 151). Seven of the 10 North Plant workers had concentrations above the median compared to only 3 of 10 at the South Plant. Similarly 7 of 10 exposed and intermediate-exposed Hardeman County participants had concentrations above the median compared to 3 of 10 study participant controls. These differences were not statistically significant, however ($p = 0.18$).

SUMMARY

Urinary thioether analysis appears to be potentially useful to document chemical exposure from industrial and water supply situations. The correlations of thioethers with Hex or Hex-BCH are not 1:1, but there were other unknown compounds also in the waste. The higher chlorinated species are expected to exhibit long biological half-lives. Thioether concentrations are expected to correlate with the presence of compounds of short half-lives in the exposing mixture such as carbon tetrachloride, tetrachloroethylene and chloroform, and hence only indirectly with the Hex and Hex-BCH levels. In situations where the major components of the waste mixture are not known, thioether determinations are expected to have their greatest potential for discriminating between exposed and non-exposed populations and for ranking exposure.

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TABLE 150. THIOETHER LEVELS IN URINE FROM SELECTED INDIVIDUALS IN EXPOSED, INTERMEDIATE-EXPOSED AND CONTROL GROUPS IN HARDEMAN COUNTY, TN

Group	Sex	Birthdate Mo/Yr.	Smoking History*	Sample Collection Data	Thioether concentration m moles SH/mole creatinine
1	M	4/45	NS	11/78	0.24
1	M	4/51	NS	11/78	4.56
1	M	10/50	S	11/78	1.08
1	F	10/51	S	11/78	5.81
1	F	1/70	NS	1/78	4.44
1	M	5/18	S	11/78	4.60
1	F	11/52	NS	11/78	3.67
1	F	11/63	NS	11/78	4.56
2	M	10/75	NS	3/79	7.67
2	M	8/18	NS	1/79	3.55
3	M	2/49	S	1/79	3.57
3	F	8/50	NS	1/79	2.80
3	M	3/50	NS	1/79	3.81
3	M	2/17	FS	1/79	4.95
3	F	2/46	NS	1/79	3.26
3	F	4/59	NS	1/79	2.64
3	F	9/68	NS	1/79	7.78
3	M	4/76	NS	1/79	1.83
3	M	10/18	NS	1/79	2.66
3	F	2/63	S	1/79	1.87

*S = Smoker, FS = Former Smoker, NS = Non-smoker.

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TABLE 151. COMPARISON OF URINARY THIOETHER CONCENTRATIONS BETWEEN GROUPS IN MEMPHIS AND HARDEMAN COUNTY

Area	Group	No. of Samples Below Median*	Above Median
(a) Memphis			
	North Plant	3	7
	South Plant	7	3
	$X^2 = 1.80$		$p = 0.18$
(b) Hardeman County			
	Exposed and Intermediate-Exposed	3	7
	Controls	7	3
	$X^2 = 1.80$		$p = 0.18$

*2.41 m mole SH/mole creatinine in Memphis and 3.62 m mole SH/mole creatinine in Hardeman County.

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APPENDIX A

Health Risks of Human Exposure to Wastewater
U.S. Environmental Protection Agency
Grant No. R 803643
(PB 81-143 406)

SECTION 3

RECOMMENDATIONS

Since the basic design of this study was to compare antibody levels between two quarters in each year of the study, all sera collected over the entire study period have not been tested. It is possible that changes in antibody levels were not detected by semiannual testing. Selected viruses of high prevalence should be studied by testing all sera for each individual.

Because the predominance of seroconversions to Hepatitis B were in the sewage-exposed groups (seven of 123 sewage-exposed workers compared to one of 52 control workers), additional testing should be done of workers not yet evaluated to determine whether this trend persists.

Additional testing of sera of workers occupationally exposed to soil, such as some sewer and highway maintenance workers, would be useful in attempting to verify previous suggestions that soil exposure increases the risk of infection to *Legionella pneumophila*.

Because of the limited testing of sera for antibody to Hepatitis A, the initial sera of a number of workers has not been tested. It would be useful to test these sera to determine whether any of these people acquired the antibody during the course of the study.

Serologic testing for rotavirus or parvovirus agent was not performed during the study. Since these viruses are now recognized as a major cause of gastrointestinal illness, the sera collected during the study should be analyzed for antibody to them.

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APPENDIX B

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UNIVERSITY OF CINCINNATI MEDICAL CENTER INFORMED CONSENT TO PARTICIPATE IN A RESEARCH STUDY

I. INTRODUCTION

The title of this study is the Public Works Employees Health Study. Before agreeing to participate in this study it is important that the following explanation of the proposed procedures be read and understood. It describes the purpose, benefits, risks and precautions of the study. It also describes the alternatives available and the right to withdraw from the study at any time. It is important to understand that no guarantee or assurance can be made as to the results.

II. OBJECTIVES

I, ______________________, of ______________________,
NAME (Please Print) STREET ADDRESS

______________, ______________, __________, ______________________,
CITY STATE ZIP TELEPHONE NUMBER

agree to participate in a medical study, the purpose of which is to investigate some of the health effects, if any, associated with public works activities such as municipal wastewater and sludge treatment, and water distribution. The benefit of this study is that if health hazards are detected in the work environment, then these results may be used to develop improved work practices. I understand that there are no immediate benefits to me but if occupational hazards are detected and corrected, I and other workers will benefit.

III. PROCEDURES

The study consists of the collection of blood (20 ml), nose and throat cultures, completion of a health questionnaire, pre and/or post shift pulmonary (lung function) studies and skin tests for all participants, and chest x-rays and physical exams for some participants.

IV. RISKS AND PRECAUTIONS

The only discomfort or risk involved will be that normally associated with the routine drawing of a small sample of blood as previously outlined. This will be performed by persons trained to do so.

V. AVAILABILITY OF INFORMATION

Any questions that I may have concerning any aspect of this investigation will be answered by Steve Bjornson, M.D.,Ph.D. (513/872-4423), or Scott Clark,Ph.D. (513/872-5784).

VI. COMPENSATION

The University of Cincinnati Medical Center follows a policy of making all decisions concerning financial compensation or medical care for injuries occurring during or caused by participation in biomedical or behavioral research on a case by case basis. If I believe I have been injured as a result of research I will contact Steve Bjornson, M.D.,Ph.D. at (513/872-4423) or Scott Clark, Ph.D. at (513/872-5784).

VII. THE RIGHT TO WITHDRAW

I am free to withdraw from this investigation at any time. I have been informed of the possible consequences of my withdrawal from the study.

VIII. Volunteer ______________________

Investigator ______________________

Witness ______________________

Date ______________________

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APPENDIX C

Public Works Employees Health Study

Health Questionnaire

11/79 Revision

Name______________________________ I.D.#____________ Birth Date____________________
(Day) (Month) (Year)

Address________________________________ ____
Street City State Zip

Social Security No. ____ - ____ - ______ Phone ____ - ____ - _______ Sex____ Race____

Number of household members_____________ Total household income_________________

Number of people outside of household dependent on family income________________

What is your job title?____

What shift do you work?____

How long have you worked for your present employer?_________________________________
(Years) (Months)

If Tyroc, when did you start composting work?____

In what area of the plant or facilities do you spend most of your time while working (refer to map?)

____

____

If more than one area, please list areas with approximate percent of time spent in each.

____

____

Aside from your present job, have you ever been engaged in sewage collection or treatment ? Yes______ No ______

If yes, what job and for how long____________________________________ ___________________
(Years) (Months)

Have you ever worked in a dusty job such as coal mine, quarry, foundry, farming, pottery, cotton, flax or hemp mill, grain elevator, etc.? Yes_____ No_____

If yes, what job and for how long____________________________________ ___________________
(Years) (Months)

Years of school________________________

Have you ever worked with or been exposed to any of the following substances? (check those materials you were exposed to)

_____ Asbestos

_____ Epoxy resins

_____ Plywood glues

_____ Solvents

_____ Urethanes

_____ Creosote

_____ Wood dusts

_____ Acid fumes

_____ Fungicides or wood preservatives

_____ Paints, varnishes, paint thinner

_____ Dyes, wood stains

_____ Grain dust (corn, wheat, hay)

Describe extent and duration of exposure, if any: ______________________________

____

____

Have you been exposed to any other chemicals, gases, fluids, dusts or materials that you or your employer consider to be dangerous or hazardous?

If so, what and for how long? ______________________________

____

____

Have you ever in your life been told by a Doctor that you ever had:

	Yes	No	Yes Formerly
Cancer or leukemia	____	____	____
Arthritis	____	____	____
Rheumatic fever	____	____	____
Heart trouble	____	____	____
Tuberculosis	____	____	____
Asthma	____	____	____
Bronchitis	____	____	____
Emphysema	____	____	____
High blood pressure	____	____	____
Diabetes (increased sugar)	____	____	____

	Yes	No	Yes Formerly
Hepatitis	____	____	____
Severe boils	____	____	____
Pneumonia	____	____	____
Pleurisy	____	____	____
Allergy	____	____	____
Hay fever	____	____	____
Sinus trouble	____	____	____
Skin problems	____	____	____
Serious accident or injury	____	____	____
Broken bones	____	____	____
Anemia	____	____	____
Pancreatitis	____	____	____
Cirrhosis of the liver	____	____	____
Eye problems (excluding glasses)	____	____	____
Ear or hearing problems	____	____	____
Food, dust or animal allergy	____	____	____
Sensitivity to chemicals	____	____	____
Weight loss or underweight	____	____	____
Overweight	____	____	____
Kidney or bladder infection	____	____	____
Blood clot in the leg	____	____	____
Blood clot to the lung	____	____	____
Positive tuberculosis skin test	____	____	____
Thyroid disease	____	____	____

Comments: ____

____

____

Immunizations

Smallpox vaccination never ____ less than 3 years ____
more than 3 years ____

Typhoid fever/paratyphoid never ____ less than 3 years ____
more than 3 years ____

Cholera never ____ less than 6 months ____
more than 6 months ____

Yellow fever never ____ less than 10 years ____
more than 10 years ____

Tetanus never ____ 0-5 years ____
over 5 years ____

Polio (oral vaccine) never ____ 0-5 years ____
over 5 years

Measles (regular) never ____ 0-5 years ____
over 5 years ____

Tuberculis immunization
(BCG vaccine, not skin test) never ____ 0-5 years ____
over 5 years ____

Have you ever undergone a surgical procedure or operation? yes ____ no ____

If yes, what body region did the operation involve?

Head/neck __________
Chest/breast ________
Abdomen, rectal, pelvic ________
Back ________
Arms/legs _______

Are you presently being treated by a Doctor for any medical or surgical problems?

yes _____ no _____

If yes, what: ____

____

Are you presently taking any medication prescribed by a Doctor?

yes _____ no _____

If yes, what medication: ____

____

Have you taken any of the following in the past month?

Antihistamines	_________
Aspirin or APC's	_________
Sleeping pills or sedatives	_________
Birth control pills (women)	_________
None of the above	_________

Have you taken any of the following in the past month?

Diet or pep pills	_________
Laxatives	_________
Diuretics or water pills	_________
Diabetic medication (oral or insulin	_________
None of the above	_________

Have you taken any of the following in the past month:

Digitalis or nitro (heart medicine)	_________
Antacids	_________
Antibiotics	_________
Blood thinner (anticoagulants)	_________

Have you taken any of the following in the past month?

Tranquilizers ________
Vitamins ________
Thyroid ________
Cortisone or steroids ________
None of the above ________

How much alcohol do you drink per week?

Specify amount and kind ________ ________

	Yes	No
Do you smoke cigarettes, cigars or a pipe regularly now?	____	____

How old were you when you started smoking? ________ (years)

How many packs, cigars, or pipes of tobacco do/did you smoke a day? ________
pipes of tobacco/day
packs/day
cigars/day

	Yes	No
Have you stopped smoking?	____	____

How old were you when you stopped smoking? ________ (years)

	Yes	No
Were you inclined to stop smoking because of a cough, wheezing or shortness of breath?	____	____

FAMILY HISTORY

	Father	Mother	Grandparent	Brother/Sister	Children
Cancer or Leukemia	___	___	___	___	___
Heart Attack or Angina	___	___	___	___	___
High Blood Pressure	___	___	___	___	___
Diabetes (Sugar)	___	___	___	___	___
Severe Obesity	___	___	___	___	___
Chronic Anemia (Poor Blood)	___	___	___	___	___
Stomach or Duodenal Ulcers	___	___	___	___	___
Thyroid Disease	___	___	___	___	___
Asthma or Other Allergic Conditions	___	___	___	___	___
Positive Tuberculosis Skin Test	___	___	___	___	___

Have You Ever Had

Radiation Treatment ___
X-Ray Treatment ___
Radioactive Isotope Treatment ___
EEG (Brain Wave) ___
Spinal Tap ___

What is the Nature of Your Daily Job Performance?

Office Work ___
Light - Physical ___
Moderate - Physical ___
Heavy - Physical ___
Drive Vehicle ___

	Healthy Generally	Chronic Illness	Died Under Age 60	Died Age 60-70	Died Over Age 70
Father	___	___	___	___	___
Mother	___	___	___	___	___
Wife/Husband (Spouse)	___	___	___	___	___

Education — How Many Years ______________

What Problems Do You Have With Your Feet?

Toe Deformity ___
Foot Swelling ___
Foot Callouses ___
Foot Sores or Rashes ___
Foot Corns or Bunions ___

Do you Get Extreme Discomfort in Your Feet and Legs?	No	___
	While Walking a Block or Two	___
	While Prolonged Standing	___
	While Lying in Bed	___
	All of the Time	___

	Yes	No
Do You Have Problems With Severe Boils or Skin Infections?	___	___
Do You Frequently Have Problems With Swollen Lymph Glands or Nodes?	___	___
Have You Had Middle or Inner Ear Infections Within the Past 5 Years?	___	___

If Yes, How Many?__________________

How Many Episodes of Illness Accompained by Diarrhea Have you Experienced Within the Past 12 Months?________________

	Yes	No
Have You Experienced Acute Onset of Diarrhea While at Work?	___	___
Do You Usually Cough First Thing in the Morning or on Getting Up? (Count a Cough With First Smoke or on First Going Out of Doors. Exclude Throat Clearing or a Single Cough.)	___	___
Do You Cough Like This on Most Days For as Much as Three Months Each Year?	___	___
Do You Cough at Work?	___	___
Do You Usually Bring Up Some Phlegm From Your Chest First Thing in the Morning or on Getting Up? (Count Phlegm With the First Smoke or on First Going Out of Doors. Exclude Phlegm From the Nose. Count Swallowed Phlegm.)	___	___
Do You Bring Up Phlegm Like This on Most Days For as Much as Three Months Each Year?	___	___
In The Past Three Years, Have You Had a Period of (Increased) Cough And Phlegm Lasting 3 Weeks or More?	___	___
Have You Had More Than One Such Period?	___	___

	Yes	No
Do You Usually Have a Stuffy Nose or Catarrh at the Back of Your Nose in the Winter?	___	___
Do You Have This in the Summer?	___	___
Do You Have This on Most Days For as Much as Three Months Each Year?	___	___
During the Past 3 Years Have You Had Any Chest Illness Which Has Kept You Off Work or From Your Usual Activities for as Much as a Week?	___	___
Did You Bring Up More Phlegm Than Usual in Any of These Illnesses?	___	___
Have You Had More Than One Illness With Phlegm Like This in the Last 3 Years?	___	___
Are You Troubled by Shortness of Breath When Hurrying on the Level or Walking up a Slight Hill?	___	___
Do You Get Short of Breath Walking With Other People of Your Own Age on Level Ground?	___	___
Do You Have to Stop for Breath When Walking at Your Own Pace on Level Ground?	___	___

Circle the Months in Which Your Shortness of Breath Has Been Most Frequent

or ( ) Check Here if There is No Relation to the Time of the Year

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	2	3	4	5	6	7	8	9	10	11	12

Have You Ever Had Asthma?

1. Yes, I Still Have it
2. Yes, But No Longer Have it
3. No

At What Age Did the Symptoms of Asthma First Start? ____________________

	Yes	No
Has Your Asthma Been Worse Since Starting Your Present Job?	___	___
Have You Noticed a Worsening of Cough and Phlegm While at Work?	___	___
Does This Go Away or Get Better on:		
Weekends Off	___	___
Vacations	___	___

	Yes	No
Does Your Chest Ever Feel Tight or Your Breathing Become Difficult?	___	___
Do You Get This Apart From Colds?	___	___

If Yes: Specify

With Exercise ___
At Work ___
Other ___________________________________

What is the Usual Color of the Phlegm Which You Bring up From Your Chest? ___________________________

	Yes	No
Does the Phlegm Contain Brown "Slugs" (Rounded Brown Dull Granular Masses About ½ Inch in Diameter)	___	___
Have You Ever Coughed Up Blood?	___	___
Are You Presently Coughing up Blood?	___	___

How Much Do You Perspire at Night in Usual Sleeping Conditions?

Not At All ___
Occasionally ___
Moisture, Body Crevices ___
Soak Night Clothing ___
Soak Sheets ___

APPENDIX D

COMPOST STUDY
COMPREHENSIVE MEDICAL AND OCCUPATIONAL HISTORY

ID Number ___ ___ ___ ___ 1 2 3 4

DATE ___ ___ ___ ___ 5 6 7 8

DATE ______________

NAME ______________

ADDRESS ______________ STREET, ______ CITY, ______ STATE, ______ ZIP

PHONE # ______________, INTERVIEWER ______________

1. DATE OF BIRTH ______ MONTH, ______ DAY, ______ YEAR ___ ___ 9 10

2. PLACE OF BIRTH ______________ ___ ___ 11 12

3. SEX:
   1. Male ______
   2. Female ______

   ___ 13

4. WHAT IS YOUR MARITAL STATUS?:
   1. Single ______
   2. Married ______
   3. Widowed ______
   4. Separated/Divorced ______

   ___ 14

5. RACE: 1. White ______ 2. Black ______ 3. Oriental ______ 4. Hispanic ______ 5. Other ______

   ___ 15

6. WHAT IS THE HIGHEST GRADE COMPLETED IN SCHOOL? ______________ ___ ___ 16 17
   (For example: 12 years is completion of high school)

NOTE: These questions pertain mainly to your chest. Please answer "yes" or "no" if possible. If a question does not appear to be applicable to you, check the "does not apply" space. If you are in doubt about whether your answer is "yes" or "no", record "no".

COUGH

7A. DO YOU USUALLY HAVE A COUGH? (Count a cough with first smoke or on first going out-of-doors. Exclude clearing of throat.) (If no, skip to Question 7C.)

1. Yes ______
2. No ______

18

B. DO YOU USUALLY COUGH AS MUCH AS 4 TO 6 TIMES A DAY, 4 OR MORE DAYS OUT OF THE WEEK?

1. Yes ______
2. No ______

19

C. DO YOU USUALLY COUGH AT ALL ON GETTING UP, OR FIRST THING IN THE MORNING?

1. Yes ______
2. No ______

20

D. DO YOU USUALLY COUGH AT ALL DURING THE REST OF THE DAY OR AT NIGHT?

1. Yes ______
2. No ______

21

IF "YES" TO ANY OF ABOVE (7A, B, C, OR D), ANSWER THE FOLLOWING:

IF "NO" TO ALL, CHECK "DOES NOT APPLY" AND SKIP TO NEXT PAGE.

E. DO YOU USUALLY COUGH LIKE THIS ON MOST DAYS FOR 3 CONSECUTIVE MONTHS OR MORE DURING THE YEAR?

1. Yes ______
2. No ______
8. Does Not Apply ______

22

F. FOR HOW MANY YEARS HAVE YOU HAD THIS COUGH? ______________________

NUMBER OF YEARS

88. Does Not Apply ______

23 24

PHLEGM

8A. DO YOU USUALLY BRING UP PHLEGM FROM YOUR CHEST? (Count phlegm with the first smoke or on first going out-of-doors. Exclude phlegm from the nose. Count swallowed phlegm.) (If "no", skip to 8C.)
1. Yes ____ 2. No ____ __ 25

B. DO YOU USUALLY BRING UP PHLEGM LIKE THIS AS MUCH AS TWICE A DAY, 4 OR MORE DAYS OUT OF THE WEEK?
1. Yes ____ 2. No ____ __ 26

C. DO YOU USUALLY BRING UP PHLEGM AT ALL ON GETTING UP, OR FIRST THING IN THE MORNING?
1. Yes ____ 2. No ____ __ 27

D. DO YOU USUALLY BRING PHLEGM AT ALL DURING THE REST OF THE DAY OR AT NIGHT?
1. Yes ____ 2. No ____ __ 28

IF "YES" TO ANY OF THE ABOVE (8A, B, C, OR D), ANSWER THE FOLLOWING:

IF "NO" TO ALL, CHECK "DOES NOT APPLY" AND SKIP TO 9A.

E. DO YOU BRING UP PHLEGM LIKE THIS ON MOST DAYS FOR 3 CONSECUTIVE MONTHS OR MORE DURING THE YEAR?
1. Yes ____ 2. No ____ __ 29
8. Does Not Apply ____

F. FOR HOW MANY YEARS HAVE YOU HAD TROUBLE WITH PHLEGM?
________ Number of Years __ 30 __ 31
88. Does Not Apply ____

EPISODES OF COUGH AND PHLEGM

9A. HAVE YOU HAD PERIODS OR EPISODES OF (increased*) COUGH AND PHLEGM LASTING FOR 3 WEEKS OR MORE EACH YEAR?
*(For persons who usually have cough and/or phlegm)
1. Yes ____
2. No ____ __ 32

IF "YES" TO 9A:

B. FOR HOW LONG HAVE YOU HAD AT LEAST 1 SUCH EPISODE PER YEAR?
________ Number of Years __ 33 __ 34
88. Does Not Apply ____

WHEEZING

10A. DOES YOUR CHEST EVER SOUND WHEEZY OR WHISTLING:

1. When you have a cold? 1. Yes _____ 2. No _____ 35

2. Occasionally apart from colds? 1. Yes _____ 2. No _____ 36

3. Most days or nights? 1. Yes _____ 2. No _____ 37

IF "YES" TO 1, 2, OR 3 IN 10A:

B. FOR HOW MANY YEARS HAS THIS BEEN PRESENT? _____ Number of Years 38 39

88. Does Not Apply _____

11A. HAVE YOU EVER HAD AN ATTACK OF WHEEZING THAT HAS MADE YOU FEEL SHORT OF BREATH?

1. Yes _____ 2. No _____ 40

IF "YES" TO 11A:

B. HOW OLD WERE YOU WHEN YOU HAD YOUR FIRST SUCH ATTACK? _____ Age in Years 41 42

88. Does Not Apply _____

C. HAVE YOU HAD 2 OR MORE SUCH EPISODES? 1. Yes _____ 2. No _____ 43

8. Does Not Apply _____

D. HAVE YOU EVER REQUIRED MEDICINE OR TREATMENT FOR THE(SE) ATTACK(S)? 1. Yes _____ 2. No _____ 44

8. Does Not Apply _____

BREATHLESSNESS

12. IF DISABLED FROM WALKING BY ANY CONDITION OTHER THAN HEART OR LUNG DISEASE, PLEASE DESCRIBE AND PROCEED TO QUESTION 14 A.

NATURE OF CONDITION(S): ______________________________ ___ 45

13A. ARE YOU TROUBLED BY SHORTNESS OF BREATH WHEN HURRYING ON THE LEVEL OR WALKING UP A SLIGHT HILL?

1. Yes ____
2. No ____

___ 46

IF "YES" TO 13A:

B. DO YOU HAVE TO WALK SLOWER THAN PEOPLE OF YOUR AGE ON THE LEVEL BECAUSE OF BREATHLESSNESS? 1. Yes ____ 2. No ____ ___ 47

8. Does Not Apply ____

C. DO YOU EVER HAVE TO STOP FOR BREATH WHEN WALKING AT YOUR OWN PACE ON THE LEVEL? 1. Yes ____ 2. No ____ ___ 48

8. Does Not Apply ____

D. DO YOU EVER HAVE TO STOP FOR BREATH AFTER WALKING ABOUT 100 YARDS (OR AFTER A FEW MINUTES) ON THE LEVEL? 1. Yes ____ 2. No ____ ___ 49

8. Does Not Apply ____

E. ARE YOU TOO BREATHLESS TO LEAVE THE HOUSE OR BREATHLESS ON DRESSING OR UNDRESSING? 1. Yes ____ 2. No ____ ___ 50

8. Does Not Apply ____

CHEST COLDS AND CHEST ILLNESSES

14A. IF YOU GET A COLD, DOES IT USUALLY GO TO YOUR CHEST? (Usually means more than ½ the time.) 1. Yes _____ 2. No _____

3. Don't get colds _____

___ 51

15A. DURING THE PAST 3 YEARS, HAVE YOU HAD ANY CHEST ILLNESSES THAT HAVE KEPT YOU OFF WORK, INDOORS AT HOME, OR IN BED? 1. Yes _____ 2. No _____

___ 52

IF "YES" TO 15A:

B. DID YOU PRODUCE PHLEGM WITH ANY OF THESE CHEST ILLNESSES? 1. Yes _____ 2. No _____

8. Does Not Apply _____

___ 53

C. IN THE LAST 3 YEARS, HOW MANY SUCH ILLNESSES, WITH (INCREASED) PHLEGM, DID YOU HAVE WHICH LASTED A WEEK OR MORE?

_____ Number of illnesses

_____ No such illnesses

8. Does Not Apply _____

___ 54

PAST ILLNESSES

16. DID YOU HAVE ANY LUNG TROUBLE BEFORE THE AGE OF 16? 1. Yes _____ 2. No _____

___ 55

17. HAVE YOU EVER HAD ANY OF THE FOLLOWING?

1A. ATTACKS OF BRONCHITIS? 1. Yes _____ 2. No _____

___ 56

IF "YES" TO 1A:

B. WAS IT CONFIRMED BY A DOCTOR? 1. Yes _____ 2. No _____

8. Does Not Apply _____

___ 57

C. AT WHAT AGE WAS YOUR FIRST ATTACK? _____ Age in years

___ 58 ___ 59

88. Does Not Apply _____

2A. PNEUMONIA (include bronchopneumonia)? 1. Yes _____ 2. No _____ ___ 60

IF "YES" TO 2A:

B. WAS IT CONFIRMED BY A DOCTOR? 1. Yes _____ 2. No _____ ___ 61

8. Does Not Apply _____

C. At what age did you first have it? _________ Age in years ___ 62 ___ 63

88. Does Not Apply _____

3A. HAY FEVER? 1. Yes _____ 2. No _____ ___ 64

IF "YES" TO 3A:

B. WAS IT CONFIRMED BY A DOCTOR? 1. Yes _____ 2. No _____ ___ 65

8. Does Not Apply _____

C. AT WHAT AGE DID IT START? _________ Age in years ___ 66 ___ 67

18A. SINUS TROUBLE? 1. Yes _____ 2. No _____ ___ 68

IF "YES" TO 18A:

B. WAS IT CONFIRMED BY A DOCTOR? 1. Yes _____ 2. No _____ ___ 69

8. Does Not Apply _____

C. AT WHAT AGE DID IT START? __________ Age in Years ___ 70 ___ 71

88. Does Not Apply _____

19A. HAVE YOU EVER HAD CHRONIC BRONCHITIS? 1. Yes _____ 2. No _____ ___ 72

IF "YES" TO 19A:

B. DO YOU STILL HAVE IT? 1. Yes _____ 2. No _____ ___ 73

8. Does Not Apply _____

C. WAS IT CONFIRMED BY A DOCTOR? 1. Yes _____ 2. No _____ ___ 74

8. Does Not Apply _____

D. AT WHAT AGE DID IT START? __________ Age in Years ___ 75 ___ 76

88. Does Not Apply _____

CARD NUMBER ___ 80

ID NUMBER ___ 1 ___ 2 ___ 3 ___ 4

20A. HAVE YOU EVER HAD EMPHYSEMA? 1. Yes _____ 2. No _____ ___ 5

IF "YES" TO 20A:

B. DO YOU STILL HAVE IT? 1. Yes _____ 2. No _____ ___ 6

8. Does Not Apply _____

C. WAS IT CONFIRMED BY A DOCTOR? 1. Yes _____ 2. No _____ ___ 7

8. Does Not Apply _____

D. AT WHAT AGE DID IT START? __________ Age in Years ___ 8 ___ 9

88. Does Not Apply _____

21A. HAVE YOU EVER HAD ASTHMA? 1. Yes _____ 2. No _____ 10

IF "YES" TO 21A:

B. DO YOU STILL HAVE IT? 1. Yes _____ 2. No _____ 11

8. Does Not Apply _____

C. WAS IT CONFIRMED BY A DOCTOR? 1. Yes _____ 2. No _____ 12

8. Does Not Apply _____

D. AT WHAT AGE DID IT START? __________ Age in Years 13 14

88. Does Not Apply _____

E. IF YOU NO LONGER HAVE IT, AT WHAT AGE DID IT STOP? __________ Age stopped 15 16

88. Does Not Apply _____

22. HAVE YOU EVER HAD:

A. ANY OTHER CHEST ILLNESS? 1. Yes _____ 2. No _____ 17

IF YES, PLEASE SPECIFY ______________________________

B. ANY CHEST OPERATIONS? 1. Yes _____ 2. No _____ 18

IF YES, PLEASE SPECIFY ______________________________

C. ANY CHEST INJURIES? 1. Yes _____ 2. No _____ 19

IF YES, PLEASE SPECIFY ______________________________

23A. HAS A DOCTOR EVER TOLD YOU THAT YOU HAD HEART TROUBLE? 1. Yes _____ 2. No _____ 20

IF "YES" TO 23A:

B. HAVE YOU EVER HAD TREATMENT FOR HEART TROUBLE IN THE PAST 10 YEARS? 1.Yes _____ 2. No _____ 21

8. Does Not Apply _____

24A.	HAS A DOCTOR EVER TOLD YOU THAT YOU HAD HIGH BLOOD PRESSURE?	1. Yes ______ 2. No ______	22
	IF "YES" TO 24A:		
B.	HAVE YOU HAD ANY TREATMENT FOR HIGH BLOOD PRESSURE (HYPERTENSION) IN THE PAST 10 YRS.?	1. Yes ______ 2. No ______ 8. Does Not Apply ______	23

TOBACCO SMOKING

25A.	HAVE YOU EVER SMOKED CIGARETTES? ("NO" means less than 20 packs of cigarettes or 12 oz. of tobacco in a lifetime or less than 1 cigarette a day for 1 year.)	1. Yes ______ 2. No ______	24
	IF "YES" TO 25A:		
B.	DO YOU NOW SMOKE CIGARETTES (as of 1 month ago)?	1. Yes ______ 2. No ______ 8. Does Not Apply ______	25
C.	HOW OLD WERE YOU WHEN YOU FIRST STARTED REGULAR CIGARETTE SMOKING?	1. Yes ______ 2. No ______ 8. Does Not Apply ______	26 27
D.	IF YOU HAVE STOPPED SMOKING CIGARETTES COMPLETELY, HOW OLD WERE YOU WHEN YOU STOPPED?	______ Age Stopped Check if still smoking ______ 88. Does Not Apply ______	28 29
E.	HOW MANY CIGARETTES DO YOU SMOKE PER DAY NOW?	______ Cigarettes per day 88. Does Not Apply ______	30 31
F.	ON THE AVERAGE OF THE ENTIRE TIME YOU SMOKED, HOW MANY CIGARETTES DID YOU SMOKE PER DAY?	______ Cigarettes per day 88. Does Not Apply ______	32 33

G. DO OR DID YOU INHALE THE CIGARETTE SMOKE?

1. Does Not Apply _____
2. Not At All _____
3. Slightly_____
4. Moderately _____
5. Deeply _____

34

26A. HAVE YOU EVER SMOKED A PIPE REGULARLY? ("YES" means more than 12 oz. of tobacco in a lifetime.)

1. Yes _____ 2. No _____

35

IF "YES" TO 26A:

FOR PERSONS WHO HAVE EVER SMOKED A PIPE:

B. 1. HOW OLD WERE YOU WHEN YOU STARTED TO SMOKE A PIPE REGULARLY?

_____ Age

36 37

2. IF YOU HAVE STOPPED SMOKING A PIPE COMPLETELY, HOW OLD WERE YOU WHEN YOU STOPPED?

_____ Age stopped

38 39

Check if still smoking a pipe _____

88. Does Not Apply _____

C. ON THE AVERAGE OVER THE ENTIRE TIME YOU SMOKED A PIPE, HOW MUCH PIPE TOBACCO DID YOU SMOKE PER WEEK?

_____ oz. per week (a standard pouch of tobacco contains 1½ oz)

40 41

88. Does Not Apply _____

D. HOW MUCH PIPE TOBACCO ARE YOU SMOKING NOW?

_____ oz. per week

42 43

88. Not currently smoking a pipe _____

E. DO YOU OR DID YOU INHALE THE PIPE SMOKE?

1. Never smoked _____
2. Not at all _____
3. Slightly _____
4. Moderately _____
5. Deeply _____

44

27A. HAVE YOU EVER SMOKED CIGARS REGULARLY? ("YES" means more than 1 cigar a week for a year.) 1. Yes _____ 2. No _____ __45

IF "YES" TO 27A:

FOR PERSONS WHO HAVE EVER SMOKED CIGARS:

B. 1. HOW OLD WERE YOU WHEN YOU STARTED SMOKING CIGARS REGULARLY? _____ Age __46 __47

2. IF YOU HAVE STOPPED SMOKING CIGARS COMPLETELY, HOW OLD WERE YOU WHEN YOU STOPPED? _____ Age stopped __48 __49
Check if still smoking _____
88. Does Not Apply _____

C. ON THE AVERAGE, OVER THE ENTIRE TIME YOU SMOKED CIGARS, HOW MANY CIGARS DID YOU SMOKE PER WEEK? _____ Cigars per week __50 __51
88. Does Not Apply _____

D. HOW MANY CIGARS ARE YOU SMOKING PER WEEK NOW? _____ Cigars per week __52 __53
88. Check if not smoking cigars currently _____

E. DO OR DID YOU INHALE THE CIGAR SMOKE? __54
1. Never smoked _____
2. Not at all _____
3. Slightly _____
4. Moderately _____
5. Deeply _____

ALCOHOL USE

28A. DO YOU DRINK ALCOHOL? 1. Yes _____ 2. No _____ __55

IF "YES" TO 28A:

B. WHAT DO YOU USUALLY DRINK? __56
1. Beer _____ 2. Wine _____
3. Liquor _____

IF "YES" TO 28A, CONTINUED:

C. HOW OFTEN DO YOU DRINK (on the average)?

1. Everyday ______
2. 3 times a week ______ 57
3. Once a week ______
4. Every other week ______
5. Once a month ______
6. Less than once a month ______

D. HOW MUCH DO YOU USUALLY DRINK AT ONE TIME OR OCCASION (one drink equals one 12 oz. beer; one 4 oz. glass of wine; or, one 1½ oz. shot of liquor)

1. 1 drink ______
2. 2 drinks ______ 58
3. 3 drinks ______
4. 4 drinks ______
5. 5 drinks ______
6. 6 drinks ______
7. More than 6 drinks ______
8. If more than 6 drinks, specify number of drinks ______

MEDICATION AND DRUG USE

29A. DO YOU TAKE ANY MEDICATION OR DRUGS (prescription, over-the counter, or street, including marijuana)? 1. Yes ______ 2. No ______ 59

IF "YES" TO 29A:

B. IF YES, SPECIFY WHAT ______________________________ 60

C. HOW OFTEN ______________________________

D. HOW MUCH OR MANY (what dose, if known) ______________________________

FAMILY HISTORY

30. WERE EITHER OF YOUR NATURAL PARENTS EVER TOLD BY A DOCTOR THAT THEY HAD A CHRONIC LUNG CONDITION SUCH AS:

	FATHER			MOTHER				
	1. Yes	2. No	3. Don't Know	1. Yes	2. No	3. Don't Know		
A. Chronic bronchitis?	____	____	____	____	____	____	61	62
B. Emphysema?	____	____	____	____	____	____	63	64
C. Asthma?	____	____	____	____	____	____	65	66
D. Lung cancer?	____	____	____	____	____	____	67	68
E. Other chest conditions?	____	____	____	____	____	____	69	70
31A. IS PARENT PRESENTLY ALIVE?	____	____	____	____	____	____	71	72

B. PLEASE SPECIFY

	FATHER	MOTHER		
	____ Age if living	____ Age if living	73	74
	____ Age at death	____ Age at death	75	76
	8. Don't know ____	8. Don't know ____	77	78

C. PLEASE SPECIFY CAUSE OF DEATH, IF KNOWN

FATHER: ____________________

MOTHER: ____________________

CARD NUMBER 80

ID NUMBER

1 2 3 4

PERSONAL HISTORY

32A. WHAT IS YOUR YEARLY HOUSEHOLD INCOME? (Include your salary and any salary earned by spouse or children that is used for supporting the household.) ____________________

5 6 7

B. HOW MANY PERSONS LIVE IN YOUR HOUSEHOLD AND ARE SUPPORTED BY THE HOUSEHOLD INCOME? ____________________

8 9

C. IS ANYONE OUTSIDE THE HOUSEHOLD DEPENDANT ON THE HOUSEHOLD INCOME? 1. Yes _____ 2. No _____

10

D. IF YES, HOW MANY PERSONS? ____________________

8. Does Not Apply________

11

JOB HISTORY

33A. WHAT IS YOUR CURRENT JOB TITLE? ____________________________

B. WHAT DOES YOUR JOB MAINLY INVOLVE?

12 13

1. _____ equipment, maintenance (other than pumping station)
2. _____ sewage pumping station maintenance
3. _____ sludge processing (other than composting)
4. _____ primary wastewater treatment
5. _____ secondary wastewater treatment
6. _____ overall plant maintenance
7. _____ sludge composting
8. _____ water meter testing and repair
9. _____ water main repair
10. _____ other, specify ______________________________

34A. WHAT WAS YOUR JOB TITLE WHEN YOU ENTERED THE HEALTH STUDY?

Date entered ____________________

Job Title ______________________________________

B. IS YOUR CURRENT JOB DIFFERENT FROM WHEN YOU ENTERED?

1. Yes _____ 2. No _____

14

IF "YES" TO 34B:

C. SINCE ENTERING THE STUDY, HOW MANY DIFFERENT JOBS HAVE YOU HAD? LIST.

1. ______________________________________

dates worked this job -- From: _____ To: _____

2. ______________________________________

dates worked this job -- From: _____ To: _____

3. ______________________________________

dates worked this job -- From: _____ To: _____

35A. DO YOU ENGAGE IN ANY TYPE OF GARDENING ACTIVITY (vegetable, flower, shrubbery, etc.)?

1. Yes _____ 2. No _____

15

B. IF YES, SPECIFY TYPE AND FREQUENCY.

____

C. IF YES, DO YOU USE ANY COMPOST OR SOIL BUILDING SUBSTANCES?

1. Yes _____ 2. No _____

16

D. IF YES, SPECIFY TYPE.

____

Card 7

APPENDIX E

COMPOST STUDY

CURRENT ILLNESS AND JOB INFORMATION

Name______________________________

Date____________________ Interviewer____________________

Month and Year of Last Interview____________________

Indicate current address or telephone number if different from last interview.

____

Treatment plant where employed____________________

Current job title (or classification) and shift, length of time this job title.

____

Describe job briefly______________________________

____

____

____

Use map to indicate approximate number of hours per day spent in various locations since our last visit.

	Hours	% of Total Time at Work
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		
M Off plant		
Specify		
Total		100%

If a compost plant worker, have you ever been in area C, even if this is not an area you are now assigned to work?____________________

Do you wear any protective clothing or equipment on the job? ___ Yes ___ No

If yes, describe the clothing and/or equipment and state when and for how long during the day it is used____________________

____

Compost start-up dates

Blue Plains	2/79	Philadelphia SW	6/76
Camden	5/78	Philadelphia NE	9/77
Beltsville	3/73		

(OVER)

Rev. 9/80

ID	1	2	3	4
Date	5	6	7	8

During the past month have you experienced any of the following?

		Yes (1)	No (2)	Unsure (3)	No. Days Work Missed		Days Missed	
9	Cough					9	10	11
12	Fever					12	13	14
15	Chills					15	16	17
18	Muscle aches					18	19	20
21	Shortness of breath					21	22	23
24	Chest pains, aching, tightness or burning					24	25	26
27	Wheezing					27	28	29
30	Stuffy nose					30	31	32
33	Eyes burning or burning					33	34	35
36	Sore throat or burning					36	37	38
39	Loss of appetite					39	40	41
42	Sudden weight loss					42	43	44
45	Diarrhea					45	46	47
48	Sores or rash on exposed skin					48	49	50
51	Headache					51	52	53

If answered "yes" to any of the above did you see a physician? ___ Yes ___ No

Elaborate on "Yes" responses (such as when do/did the symptoms occur, was it in relation to work, how long does/did it last, how often does/did it happen, etc.).

APPENDIX F

University of Cincinnati Medical Center
Public Works Employees Health Study

Physical Examination

Date performed ____________________

Relation at the time of physical examination to work day: pre shift _______

mid shift _______

post shift _______

Study participant:

Name __________________________________

Address __________________________________

____

Social Security No. _____ - ___ - _____

Date of birth ________________

Sex M F

Blood pressure ______________ Pulse rate ______

Respiratory rate ____________ Height (inches) _____

Body weight (lbs.) __________

Stature: ________ Normal

________ Obese

________ Significant skeletal or neuromuscular deformity

Please specify ____

____

Skin and extremities:

Cyanosis ________ None

________ Questionable

________ Definite

(Skin and extremities cont.)

Clubbing ________ None

________ Questionable

________ Definite

Evidence of active or healed skin abscesses, carbuncles, or furuncles

________ None

________ Questionable

Distribution: ____

____
(active or healed lesions)

Evidence of other cutaneous infections

________ None

________ Definite

Please describe: ____

____

Other abnormalities of skin or extremities, please describe: ____

____

____

Eyes:

Conjunctiva ________ Normal

________ Abnormal

Describe abnormality: ____

____

Orbitopalpebral grooves

________ Normal

________ Edematous

________ Discoloration

Describe abnormality: ____

____

(Eyes cont.)

Ophthalmoscopic examination

________ Normal

________ Abnormal

Describe abnormality: ______________________________

____

Describe any other abnormalities noted: ____________________

____

Ears: ________ Normal

________ Defects

Describe defect: ______________________________

____

Nose:

Inferior turbinates ________ Normal

________ Engorged

________ Mucoid secretions present

Septum ________ Midline

________ Deviated

Comment: ______________________________

____

Pulmonary examination:

Respiratory distress at rest ________ None

________ Tachypnea and/or hyperpnea

________ None at rest but present
with slight exertion

________ Severe and obvious (hyper-ventilation, use of accessory
muscles, asthmatic attack)

(Pulmonary examination cont.)

Chest configuration
________ Normal
________ Mild Kyphoscoliosis
________ Moderate to severe Kyphoscoliosis
________ Increased A-P diameter
________ Other (Please specify)

Breath sounds
________ Normal bilaterally
________ Decreased-localized
________ Decreased-generalized
________ Other (Please specify)

Wheezing
________ None
________ Occasional-scattered
________ Elicited by forced expiration only
________ Obvious and generalized
________ Other (Please specify)

Rales
________ None
________ Inspiratory crepitant (dry) unilateral
________ Inspiratory crepitant (dry) bilateral
________ Moist rales - unilateral
________ Moist rales - bilateral
________ Other (Please specify)

Other significant abnormalities
________ Yes (describe)
________ No

____

____

____

Cardiovascular examination:

Rhythm ________ regular

________ irregular

________ irregularly/irregular

Murmurs or gallops

________ Absent

________ Present - please

describe ____

____

Approximate location of PMI

____

Peripheral pulses

________ Normal

________ Diminished

Other abnormalities, please describe: ________________________

____

____

Abdominal examination:

Bowel sounds

________ Normal

________ Abnormal - please

describe ____

____

Masses ________ Absent

________ Present - please describe location,

size, and characteristics ____________________________

____

(Abdominal examination cont.)

Spleen _______ Not palpable

_______ Palpable

Liver span (estimated) in MCL _______________ cm

Other abnormalities, surgical scars, etc., please describe: _____

____

Neurologic examination:

Please describe any abnormalities observed in:

Cranial nerve function _________________________________

____

Motor function ____

____

Reflexes ____

____

Sensation ____

____

Mental status ____

____

Rectal examination (optional):

_______ Normal

_______ Abnormal, describe ____________________________

____

Any other abnormalities observed___________________________

____

____

Examining physician

____

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

APPENDIX G

BIOLOGICAL AND SAMPLING PROCEDURES

Definitions from "Microbiological Methods for Monitoring the Environment: water and wastes", edited by Robert Bordner, John Winter, and Pasquale Scarpino. EPA-600/8-78-017, December 1978.

Coliforms: aerobic and facultative anaerobic, gram-negative nonspore-forming, rad shaped bacteria that ferment lactose in 24-48hr ant 35C. The coliform group includes *Escherichia*, *Citrobacter*, *Enterobacter*, and *Klebsiella*.

Fecal coliforms: gram-negative nonspore-forming rods that ferment lactose in 24±2hr at 44.5C with production of gas in a multiple-tube procedure or produce acidity with blue colonies in a membrane filter procedure. The major species in *E. coli*.

Fecal streptococci: species of *Streptococcus* which indicate the sanitary quality of water and wastewater. The fecal strep group includes Lancefield's serologic groups D and Q.

Group D	*S.* faecalis	Enterococcus Group
	S. faecalis subsp. liquefaciens	
	S. faecalis subsp. zymogenes	
	S. faecium	
	S. bovis	
	S. equinus	
Q	*S.* avium	

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Counting colonies and recording colony counts

1. Count all colonies on a plate if the colony numbers are not high enough to preclude this and if no areas of confluent growth are present.

2. If colony numbers preclude counting all colonies, count the colonies on one-quarter of the plate and multiply the value obtained by four. Use the colony counter grid to determine one-quarter of the plate. Choose for counting an area of the plate which is "typical" in terms of colony numbers. When counting colonies on one-quarter of the plate, count any colony which touches the horizontal boundary marker line and count none of the colonies which touch the vertical boundary marker line.

3. Convert plate count numbers to the number of bacteria or fungi per cubic meter of ambient air.

$$\frac{\text{Actual colony count of plate}}{\text{Duration of sample collection (min) at 1 cuf/min}} =$$

= Bacteria or fungi/cubic foot of air x

x 28.317 = bacteria or fungi/cubic meter.

This foumula can be used to determine total bacterial and fungal count, total coliforms, fecal coliforms, fecal strep, Salmonella, Shigella, Aspergillus, and other thermophilic fungi.

Laboratory handling of Anderson Sampler plates

When Anderson sampler plates are returned to the laboratory: incubate bacterial plates (TSA) (usually marked with a "B") at 37 C for 24hr; incubate fungal plates (CDB) (usually no medium identification marked on plate) at 44.5 C for 48hr.

Fungal plates
44.5 C, 48hr.

Bacterial plates
37 C, 24hr.

↓

1. Count bacterial colonies on original TSA plates. Record as total bacterial count.

2. Each TSA plate with bacterial growth should be replicate plated to M-FC Agar, M-Endo Agar, and KF Streptococcus Agar. HEA, XLD, and SS agars--see 4. below.

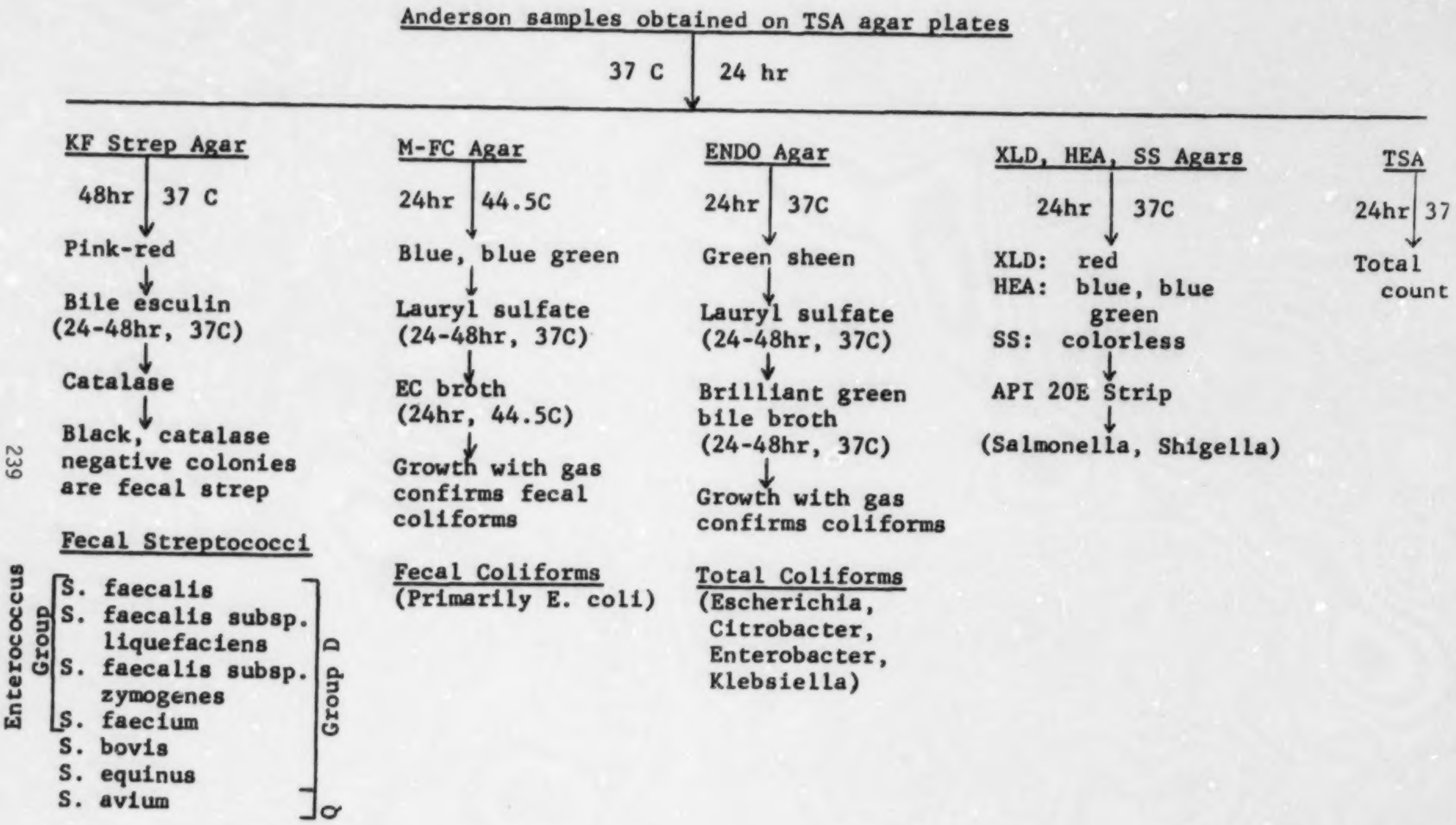
M-FC Agar
44.5 C ↓ 24hr
Blue, blue-green colonies are fecal coliforms. Pick to:
↓
Lauryl Sulfate Broth
(24-48hr, 37C)
EC Broth
(24hr, 44.5C)
↓
Growth with gas confirms fecal coliforms

M-Endo Agar
37 C ↓ 24hr
Green sheen colonies are coliforms. Pick to:
↓
Lauryl Sulfate Broth
Brilliant Green Bile Broth
37 C ↓ 48±3hr
Growth with gas confirms presence of coliform (total)

KF Strep Agar
37 C ↓ 48hr
Pink-red-purple colonies are fecal strep. Pick to:
↓
Bile Esculin Agar
37 C ↓ 24hr
Add 3% peroxide to black colonies for catalase test
↓
Black catalase negative colonies are fecal strep.

3. After 48hr at 44.5 C, count fungal colonies. List as "Aspergillus" and "other fungi".

4. HEA, XLD, and/or SS agars may be replicate plated from the original TSA plates at the same time other plates are replicated. Salmonella and Shigella strains form blue, blue-green colonies on HEA; red colonies on XLD; and clear colonies on SS. Pick such colonies to API 20E strips for identification. Stock all strains identified as Salmonella or Shigella.


Anderson samples obtained on TSA agar plates
37 C
24 hr
KF Strep Agar
48hr
37 C
Pink-red
Bile esculin
(24-48hr, 37C)
Catalase
Black, catalase negative colonies are fecal strep
Fecal Streptococci
Enterococcus Group
S. faecalis
S. faecalis subsp. liquefaciens
S. faecalis subsp. zymogenes
S. faecium
S. bovis
S. equinus
S. avium
Group D
Q
M-FC Agar
24hr
44.5C
Blue, blue green
Lauryl sulfate
(24-48hr, 37C)
EC broth
(24hr, 44.5C)
Growth with gas confirms fecal coliforms
Fecal Coliforms
(Primarily E. coli)
ENDO Agar
24hr
37C
Green sheen
Lauryl sulfate
(24-48hr, 37C)
Brilliant green bile broth
(24-48hr, 37C)
Growth with gas confirms coliforms
Total Coliforms
(Escherichia, Citrobacter, Enterobacter, Klebsiella)
XLD, HEA, SS Agars
24hr
37C
XLD: red
HEA: blue, blue green
SS: colorless
API 20E Strip
(Salmonella, Shigella)
TSA
24hr
37
Total count

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KF Streptococcal Agar (BBL)

76.4g/liter distilled water

Boil 5 min with frequent agitation, cool to 50-60 C and add 10 ml of 1% triphenyl tetrazolium chloride per liter of medium (0.1g TTC in 10ml water, filter sterilize). Do not autoclave.
Alternatively, the medium may be autoclaved at 121C for 10 min and the TTC added after cooling to 50-60C.
Final pH should be 7.2. Dispense 25-30ml per plate.

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M-Endo Agar (LES) (BBL)

50g/liter distilled water containing 20ml ethanol.

Heat until agar melts, cool to 50-60C and dispense 25-30ml per plate. Final pH should be 7.2. This medium should be made on the day of use.

M-FC Agar

37g M-FC Broth (BBL)
20g Agar
1000ml distilled water containing Rosolic acid.
    Rosolic acid; add 0.1g to 10ml of 0.2N NaOH and
        add this 10ml to 1000ml distilled water.

Heat to boiling, cool to 50-60C, and dispense 25-30ml per plate. Do not autoclave medium. Final pH should be 7.4.

Bile Esculin Agar (Difco)

64g/liter distilled water

Autoclave at 121C for 15 min, cool to 50-60C and dispense 25-30ml per plate. Final pH should be 6.6.

Brilliant Green Bile Broth (BBL)

40g/liter distilled water

Dispense 6-7 ml samples into 16x150mm tubes, add inverted sand tube, cover with Morton closure, and autoclave at 121C for 12-15 min. Cool as rapidly as possible. Final pH 7.2.

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CZAPEK-DOX BILE AGAR

Czapek-Dox Broth (Difco)	35 g
Agar (Difco)	20 g
Oxgall (MCB)	15 g
Distilled water	1000 ml

pH to 7.3, autoclave, cool to 50 C and add the following antibiotics.

Streptomycin	50 mg	(50 µg/ml)
Cholramphenicol	50 mg	(50 µg/ml)
Penicillin	20,000 U	(20 Units/ml)

Dispense 27 ml/Anderson plate

Use in the Anderson air sampler for the isolation of *Aspergillus* from aerosol samples.

TRYPTICASE SOY AGAR

Trypticase Soy Agar (BBL)	40 g
Distilled water	1000 ml

pH to 7.3, autoclave, cool to 50 C, and dispense 27 ml/ Anderson plate.

Use in the Anderson air sampler for the isolation of bacteria from aerosol samples.

MEDIA

EC Broth (BBL)

36.5g/liter distilled water

Dispense 6-7ml samples into 16x150mm tubes, add inverted sand tube, cover with Morton closure, and autoclave at 121C for 15 min. Final pH should be 6.9.

Lauryl Sulfate Broth (BBL)

35.6g/liter distilled water

Dispense 6-7ml samples into 16x150mm tubes, add inverted sand tube, cover with Morton closure, and autoclave at 121C for 15 min. Cool as rapidly as possible. Final pH should be 6.8.

APPENDIX H

A QUANTITATIVE CHEMICAL MARKER FOR ENDOTOXIN: GC QUANTITATION OF β-HYDROXYMYRISTIC ACID*

Kirschner, D., Que Hee, S. S. and Clark, C. S., Department of Environmental Health, University of Cincinnati Medical Center, 3223 Eden Avenue, Cincinnati, Ohio 45267.

Abstract

The increased use of sewage sludge composting facilities may cause the exposure of workers and nearby communities to large amounts of airborne endotoxin, or cell wall lipopolysaccharide from gram negative bacteria. Clinical manifestations of probable endotoxin exposure have been reported in compost workers. A gas chromatography method was developed to quantitate a derivatized fatty acid marker of endotoxin, the methyl ester of β-hydroxymyristic acid. The marker is an integral part of the toxic complex of endotoxin, lipid-A. The method development involved the optimization of hydrolysis times and extraction technique. Confirmation of the gas chromatograph fatty acid marker peak was done by mass spectroscopy. A multi-column GC approach was also evolved. Endotoxin in lipopolysaccharide and _E. coli_ as well as compost was quantified.

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*Presented at poster session of 1982 American Industrial Hygiene Association Conference.

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METHODS

Summary: After prior clean-up of ground, dry compost with a methanol extraction, betahydroxymyristic acid is released from its Lipid-A bound form by hydrolysis in 8 M HCl. The acidic components are extracted with diethyl ether, then subjected to alkaline hydrolysis and clean-up (hexane extraction). The alkaline residue is acidified to pH 6 (H_3PO_4), the free fatty acids extracted with diethyl ether, and the free fatty acids methylated with 5% dimethyl sulfate/methanol. The fatty acid ester is stored in 1,2-dichloroethane/water. The ester is now ready for flame ionization gas chromatographic analysis (Figure 5,6) or GC/MS.

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AIMS

TO EVOLVE A CHEMICAL MARKER METHOD FOR THE ENDOTOXIN OF GRAM-NEGATIVE BACTERIA, E.G. SALMONELLA, ESCHERICHIA, IN COMPOST.

APPLICATIONS

1. TO QUANTITATE THE PRESENCE OF SUCH BACTERIA OR THEIR DETRITUS SO AS TO DEFINE CRITICAL LEVELS OF THE CHEMICAL MARKER USEFUL TO INDICATE ADVERSE EFFECTS, AND TO FACILITATE BIOLOGICAL MONITORING, E.G. OF THE URINE OR BLOOD, OF OCCUPATIONAL PERSONNEL SUCH AS SEWAGE SLUDGE COMPOSTING WORKERS, OR OF PATIENTS WITH INFECTIONS RELATED TO THE PRESENCE OF BACTERIA.
2. TO COMPLEMENT THE LIMULUS AMOEBOCYTE BIOLOGICAL ASSAY, AND PERHAPS TO REPLACE THIS TEST EVENTUALLY WITH AN INSTRUMENTAL, OBJECTIVE TEST. THE LIMULUS TEST IS NOT SPECIFIC FOR ENDOTOXIN.
3. TO EXTEND THE CHEMICAL MARKER METHOD TO LIVESTOCK OPERATIONS, FARMING, COTTON AND FLAX PRODUCTION AND MILLING, AND OTHER SITUATIONS WHERE GRAM-NEGATIVE BACTERIA ARE PREVALENT.

PRINCIPLE OF TECHNIQUE

1. BETA-HYDROXYMYRISTIC ACID IS A CHARACTERISTIC FATTY ACID OF THE ENDOTOXIN OF MOST GRAM-NEGATIVE BACTERIA (FIGURE 1). ENDOTOXIN IS ATTACHED TO THE OUTSIDE MEMBRANE OF THE BACTERIAL CELL (FIGURE 2).
2. THE ENDOTOXIN OF GRAM NEGATIVE BACTERIA CONSISTS OF LIPID-A AND POLYSACCHARIDE UNITS (FIGURES 2, 3). THE LIPID-A UNIT CONTAINS FOUR SATURATED FATTY ACIDS: BETAHYDROXYMYRISTIC (C_{14}; APPROX. 60%), DELTA^2-TETRADECENOIC (C_{14}), PALMITIC (C_{16}) AND LAURIC (C_{12}) ACIDS (SEE FIGURES 1 AND 3). LIPID-A PRESENCE IS ESSENTIAL TO PRODUCE BIOLOGICAL EFFECTS.

METHODS

SAMPLE PREPARATION:

1. Dry compost sample at 75°C for three hours.
2. Mortar and pestle the material and remove large particles and metallic pieces.
3. Reflux compost (0.5g) in methanol (10 mL) for 1 hour.
4. Remove the methanol after centrifugation (1000 g for 5 min.)
5. Dry the residue with a stream of nitrogen.
6. Add 8 M HCl/5mL) and reflux (85 ± 10°C for 3 hours).
7. Extract the cooled solution with diethyl ether (5 mL x 3).
8. Amalgamate the extracts; add 10% aqueous potassium hydroxide (2 mL), and evaporate the ether.
9. Shake the solution well. Wash with hexane (2 mL), centrifuge and discard the hexane.
10. Add 1 M phosphoric acid to adjust the pH to 6.0 (usually 2.8 mL).
11. Shake well, then extract with diethyl ether (3 mL x 3), centrifuging before each separation.
12. Combine the extracts, evaporate the ether (N_2 stream, add methanol (1 mL) and vortex (10 sec).
13. Add 5% dimethyl sulfate in methanol (3 mL); reflux for 30 min. at 85°C.
14. After cooling, add 1,2-dichloroethane (0.5 mL). Evaporate the methanol.
15. Add distilled water (4 mL) and shake. Centrifuge.
16. Inject 1 μL from the 1,2-dichloroethane layer into the gas chromatographic column.

GAS CHROMATOGRAPHIC OR GC/MS ANALYSIS:

Two methods of analysis were performed.

A. Two Column GC Analysis:

(1) 10% Silar 10-CP on Chromosorb W-HP (100/120 mesh) in 1.87 m X 2 mm ID pyrex column; He carrier (30 mL/min). Temperatures: injector (225°C), flame ionization detector (280°C). Column: Hold at 150°C for 8 minutes; heat 4°/min to 220°C. See Figure 5.

(2) 10% FFAP/1% phosphoric acid impregnated Chromosorb W-HP (100/120 mesh) in 1.87 m X 2 mm ID pyrex column; he carrier (30 mL/min), Temperatures: injector (225°C), Column: (190°C), and flame ionization detector (280°C).

FID detector: H_2 (30 mL/min); air (240 mL/min).

B. GC/MS

Same column as A(1) but situated in a Finnegan Quadrupole Mass Spectrometer 4023 System, equipped with an INCOS Data System. The mass spectrum is given in Figure 6.

QUANTITATION:

Calibration was accomplished via a calibration curve constructed using authentic β-hydroxymyristic and methyl ester.

Recovery of Method: (86 ± 5)% by the Method of Standard Additions

Methylation Efficiency: (87 ± 3)%

Optimization of Compost Hydrolysis Time: 3 hours (Figure 7)

Sensitivity: 5 ng of β-hydroxymyristic acid as the methyl ester

Standard Additions/External Standard:

	External Standards	Standard Additions
Comparison:	18.7 ± 0.7	18.4 ± 0.7

Units: µg BHM acid/g compost

Bacterial Parameters:

	GC Column	
	Silar 10-CP	FFAP
µg BHA/mg *E. coli* whole cells	2.9 ± 0.1	2.4 ± 0.1
µg BHA/mg *E. coli* lipopolysaccharide	-	56.1 ± 2.2
µg BHA/g compost	18.7 ± 0.7	10.6 ± 0.4

CONCLUSIONS

1. THIS GC/MS TECHNIQUE IS AN INSTRUMENTAL METHOD OF GREAT SENSITIVITY FOR THE PRESENCE OF ENDOTOXIN WHICH IS A CHEMICAL MARKER OF THE PAST PRESENCE OF GRAM-NEGATIVE BACTERIA.
2. THE COMPOST EXAMINED CONTAINED AN *E. COLI* EQUIVALENT OF 190 MICROGRAM PER GRAM OF COMPOST.
3. THIS METHOD IS MORE SENSITIVE THAN THE *LIMULUS* BIOASSAY.

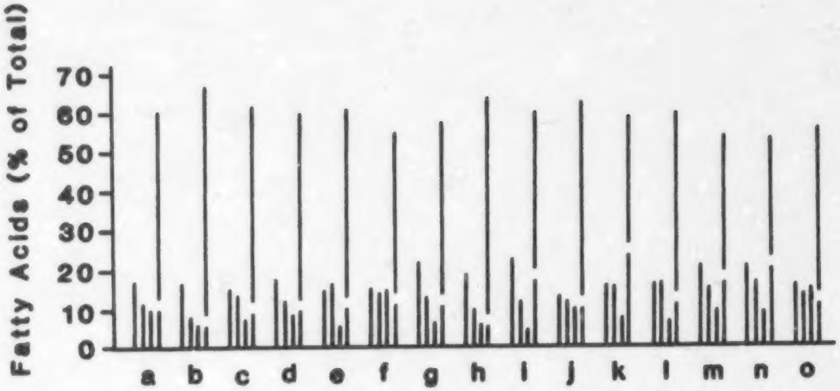

Figure 1:

SCHEMATIC REPRESENTATION OF THE FATTY-ACID COMPOSITION OF THE LIPID-A COMPONENT OF LIPOPOLYSACCHARIDES OF VARIOUS SALMONELLA STRAINS. THE COLUMNS OF EACH SET REPRESENT (LEFT TO RIGHT): LAURIC, MYRISTIC, PALMITIC, AND DELTA^{2}-TETRADECENOIC (LOWER PART) AND BETAHYDROXYMYRISTIC ACID (UPPER PART).

STRAINS:
a: S. ABORTUS EQUI
b: S. TYPHIMURIUM
c: S. TYPHIMURIUM R1195
d: S. GODESBERG
e: S. FRIEDENAU
f: S. MINNESOTA
g: S. MINNESOTA R60
h: S. MINNESOTA R345
i: S. MINNESOTA R5
j: S. MINNESOTA RZ1
k: S. MINNESOTA RZ2
l: S. MINNESOTA R7
m: S. MINNESOTA R3
n: S. MINNESOTA R4
o: S. MINNESOTA R595

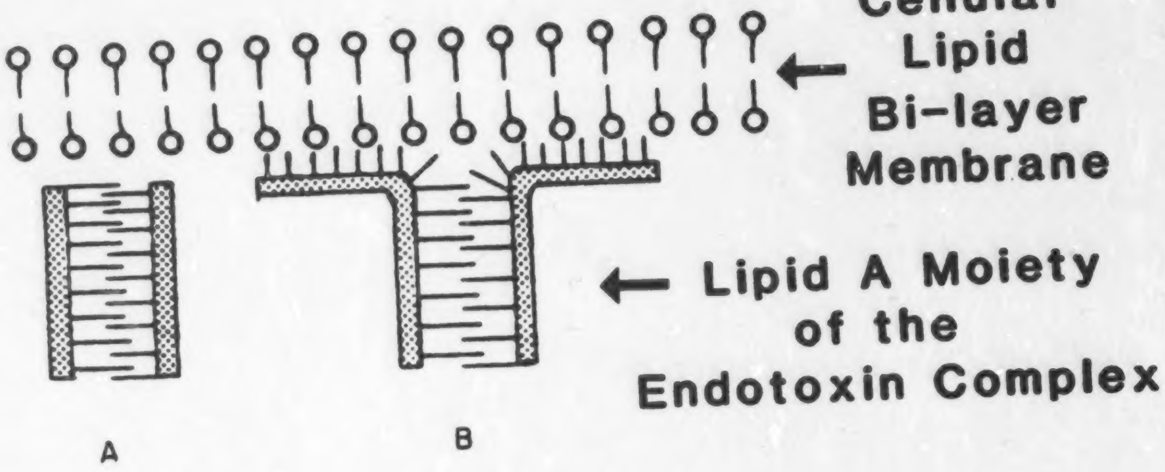
Cellular
Lipid
Bi-layer
Membrane
Lipid A Moiety
of the
Endotoxin Complex
A
B

Figure 2:

MODEL FOR THE ATTACHMENT OF ENDOTOXIN TO CELLULAR LIPID BILAYER MEMBRANES E.G. OF ERYTHROCYTES. A: EDGE ATTACHMENT BY WHICH SOME FATTY ACIDS OF LIPID A MOIETIES OF ENDOTOXIN MIGHT BE SOLUBILIZED INTO THE BILAYER. B: OPEN BILAYER ALLOWING INTERACTION OF THE LIPID A FATTY ACIDS WITH THE BILAYER; THIS IS THOUGHT TO BE THE STATE IN SALMONELLA.

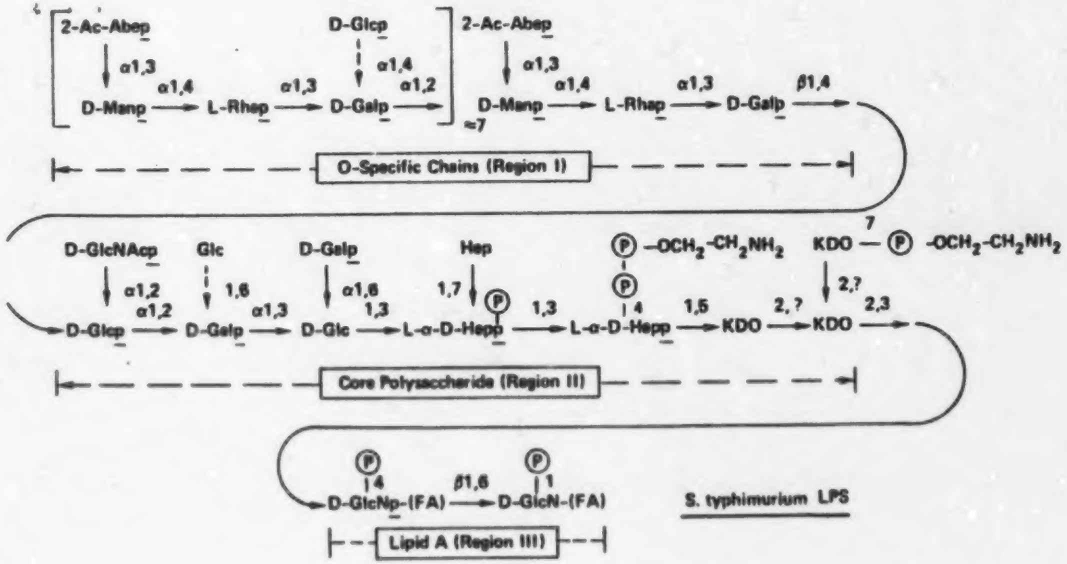
2-Ac-Abep
α1,3
D-Manp
α1,4
L-Rhap
α1,3
D-Glcp
α1,4
D-Galp
α1,2
≈7
β1,4
O-Specific Chains (Region I)
D-GlcNAcp
Glc
D-Galp
Hep
α1,2
1,6
α1,6
1,7
D-Glcp
D-Galp
D-Glc
L-α-D-Hepp
1,3
1,5
2, ?
2,?
2,3
KDO
7
4
P
-OCH2-CH2NH2
Core Polysaccharide (Region II)
D-GlcNp-(FA)
β1,6
D-GlcN-(FA)
1
Lipid A (Region III)
S. typhimurium LPS

Figure 3:

CHEMICAL STRUCTURE OF THE LIPOPOLYSACCHARIDE CHAIN OF SALMONELLA TYPHIMURIUM (LUDERITZ ET. AL., 1971).

Gal= GALACTOSE; Glc= GLUCOSE; Man= MANNOSE; Rha= RHAMNOSE; Hep= 1-GLYCERO-D-MANNOHEPTOSE; GlcNp= GLUCOSAMINE; GlcNAcpNAC= N-ACETYL GLUCOSAMINE; KDO= 2-KETO-3-DEOXYOCTANATE; p= PYRANOSE; P= PHOSPHATE; FA= LONG CHAIN FATTY ACIDS SUCH AS BETAHYDROXYMYRISTIC, MYRISTIC, PALMITIC, AND LAURIC.

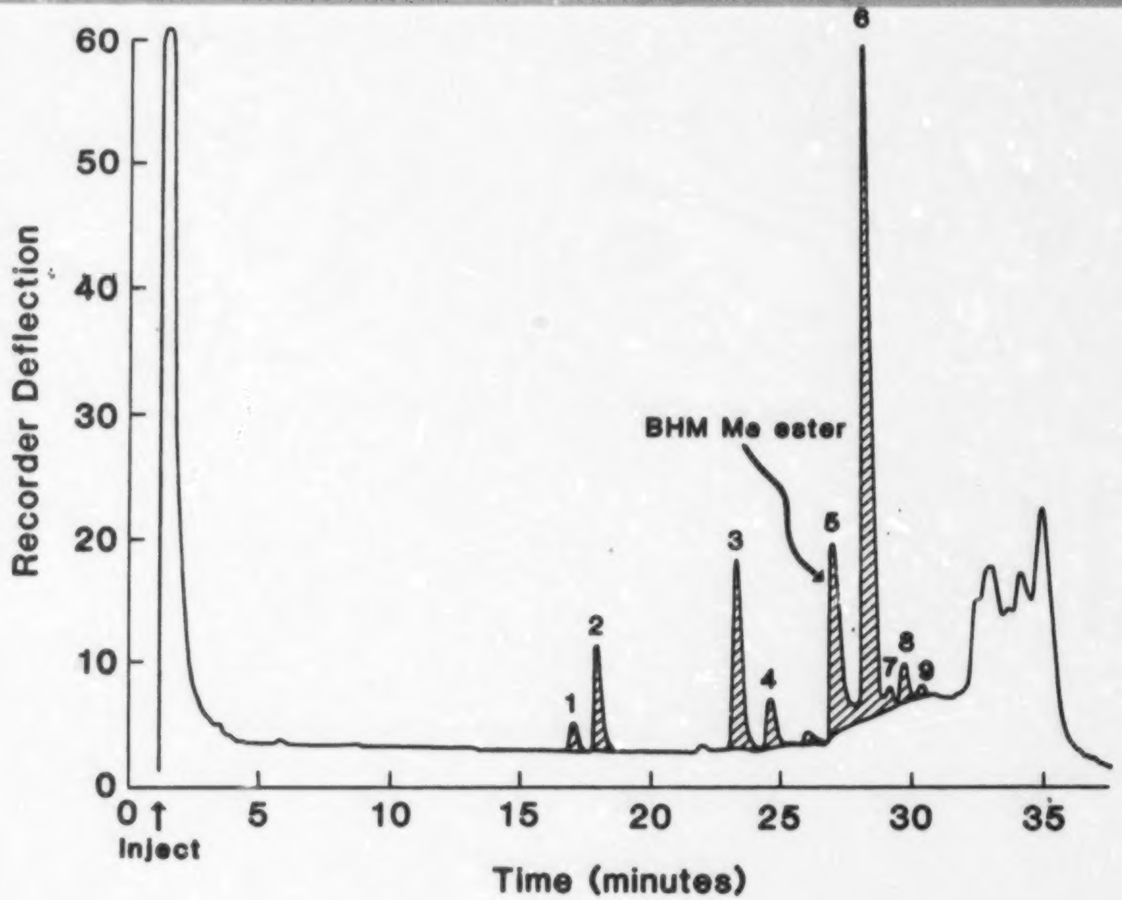

Figure 4:

CHROMATOGRAM OF THE FATTY ACID ESTERS FROM E. COLI AFTER A THREE HOUR HYDROLYSIS WITH 8M HCL (NO METHANOL CLEAN-UP).

COLUMN: 20 IN X 1/8 IN 10% UCW-92 ON CHROMOSORB HP.
CARRIER: HELIUM (38 ML/MIN)
TEMPERATURES: 250 C (INJECTOR;FLAME IONIZATION DETECTOR)
COLUMN: 70 C (8 MIN.); 8 C/MIN TO 200 C; HOLD.

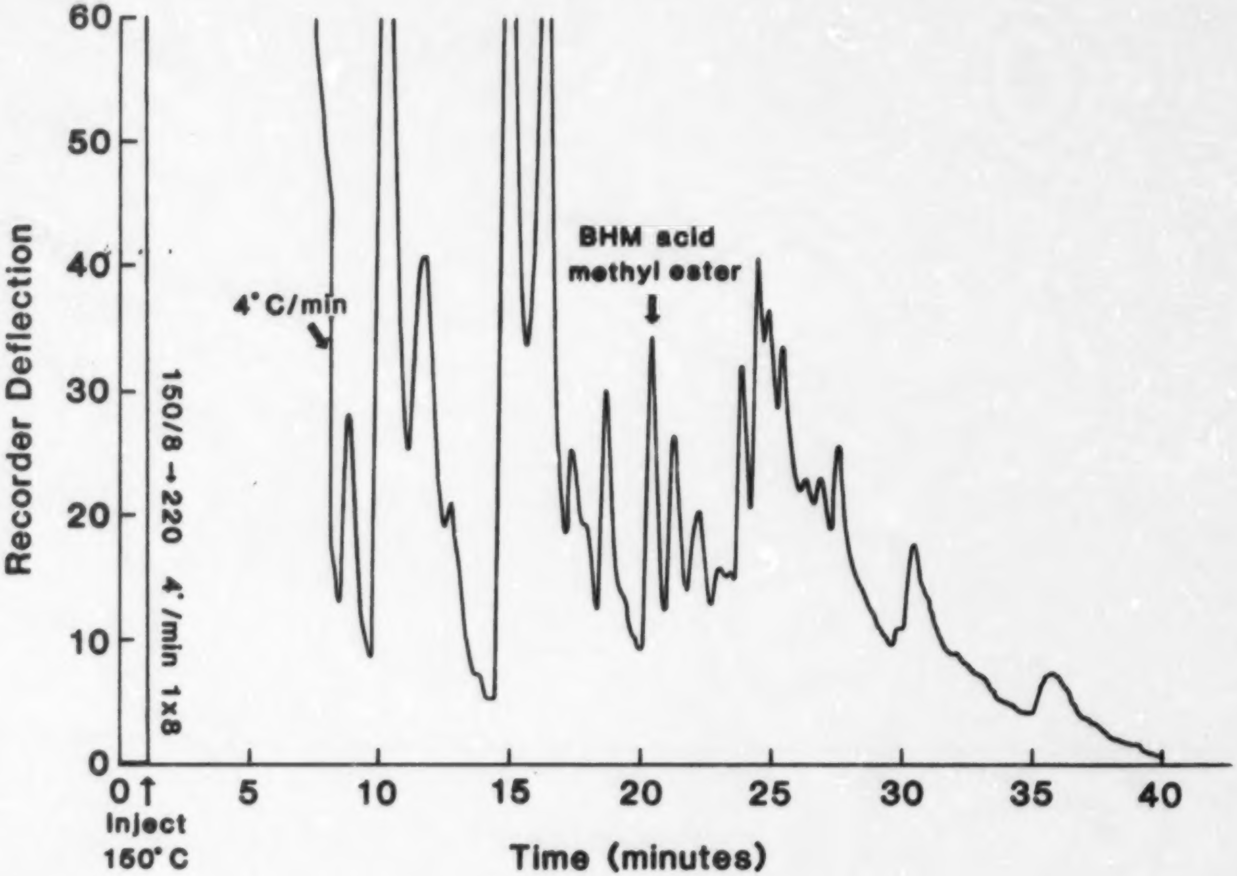

Figure 5:

CHROMATOGRAM OF THE FATTY ACID ESTERS FROM COMPOST (0.75 MG).

COLUMN: 6 FT. X 2 MM I.D. 10% SILAR 10C-P
CARRIER: HELIUM (44 ML/MIN)
TEMPERATURES: 250°C (INJECTOR; FLAME IONIZATION DETECTOR)
COLUMN: 150°C (8 MIN); 4°C/MIN TO 220°C;
220°C (15 MIN)

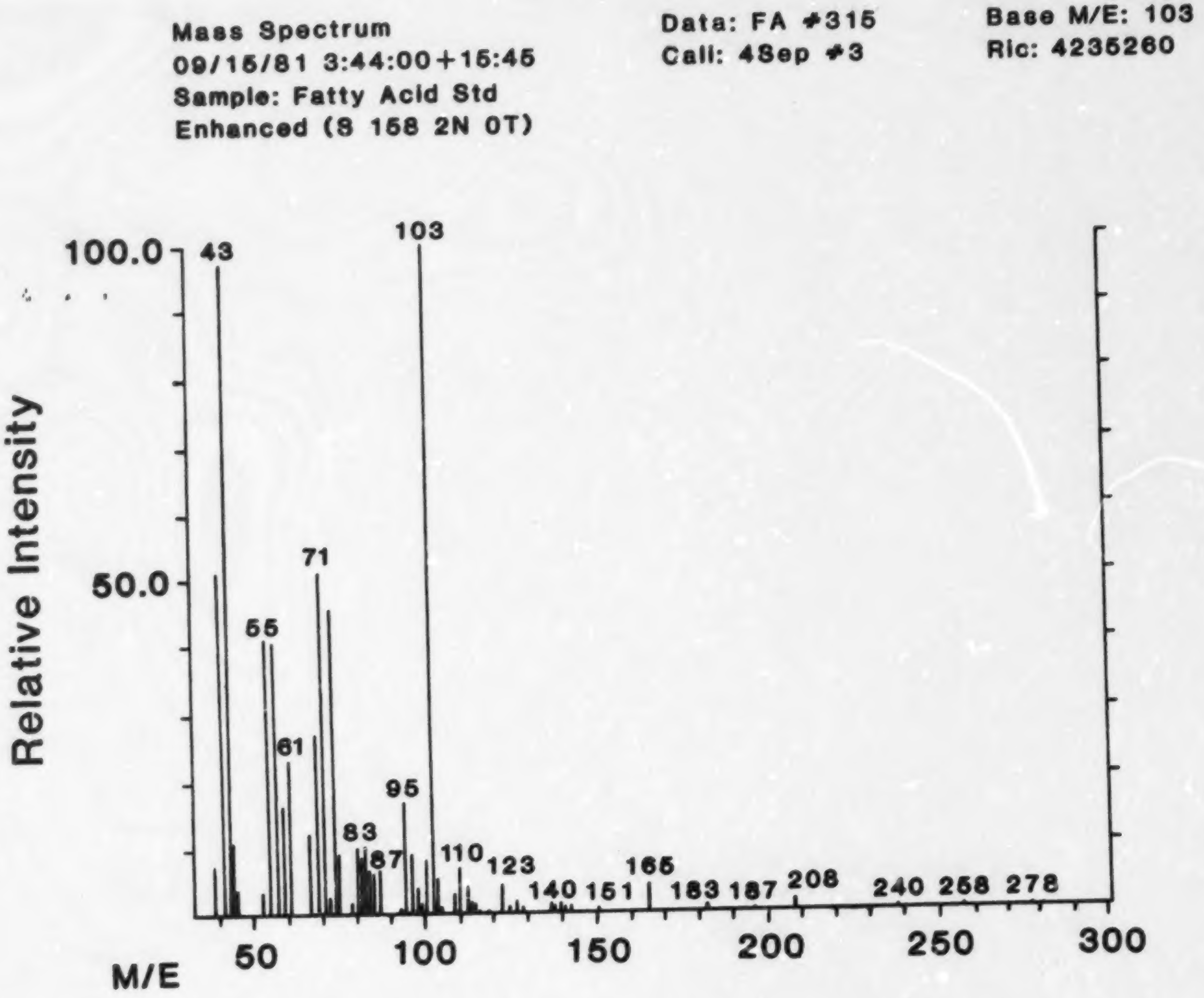

Figure 6:

MASS SPECTRUM OF THE METHYL ESTER OF BETAHYDROXYMYRISTIC ACID.

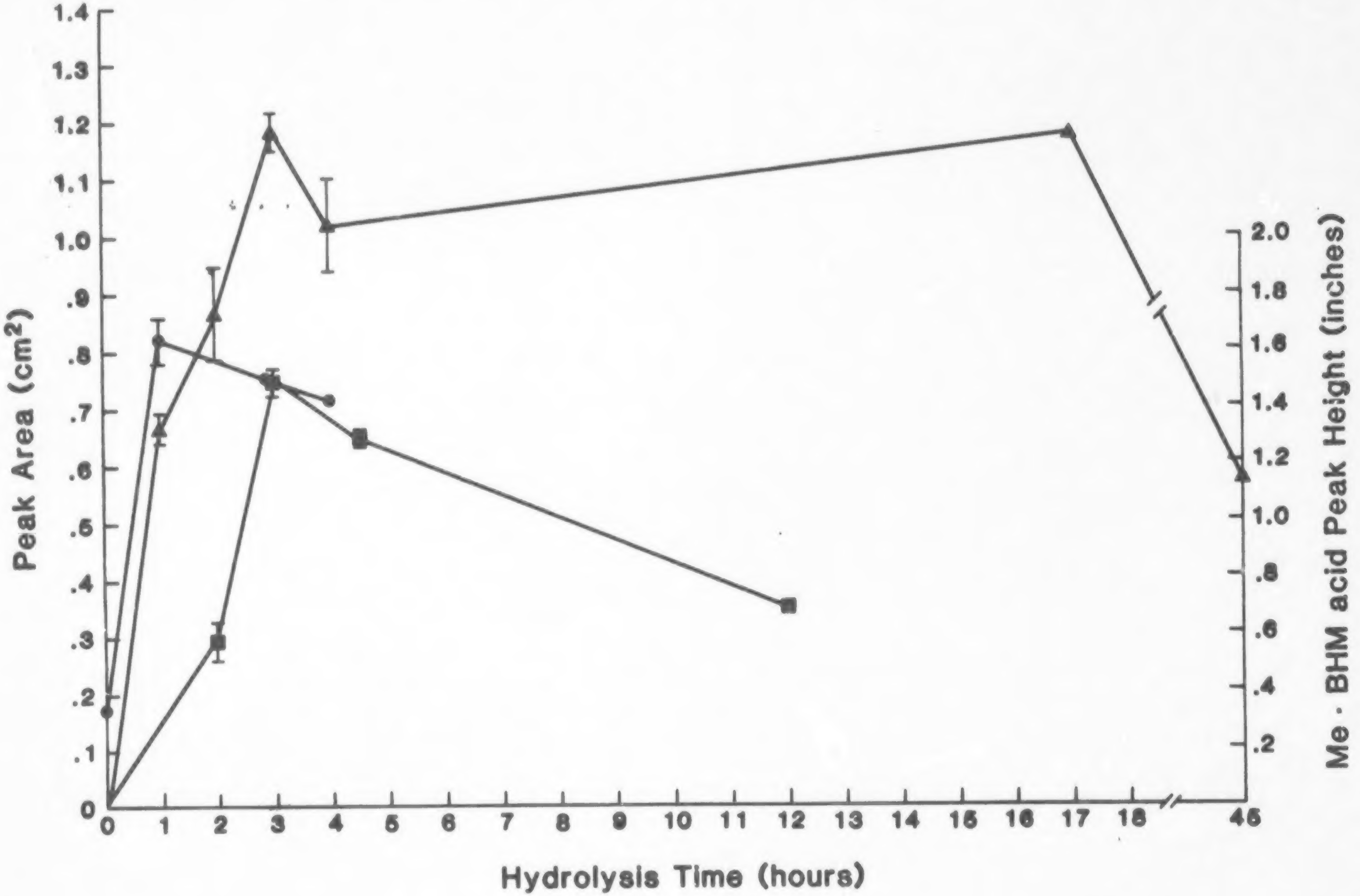

Figure 7:

ACID HYDROLYSIS (8M HYDROCHLORIC) TIME STUDIES FOR LIPOPOLYSACCHARIDE, E. COLI WHOLE CELLS, AND COMPOST.

AMOUNT OF METHYLATED BETAHYDROXYMYRISTIC ACID RELEASED VERSUS HYDROLYSIS TIME

COMPOST

APPENDIX I

SUMMARY OF THE 18 KNOWN CONFIRMED HUMAN CASES OF PROTOTHECOSIS

Case No.	Patient's Age-Sex	Geographic Location	Site of Lesions	Associated Disease or Conditions
1	30-M	Sierre Leone	Foot, lymphnodes	Rice farmer
2	45-F	North Carolina	Leg	Metastatic carcinoma, diabetes mellitus
3	Adult-M	S. Africa	Forehead and scalp	Not known
4	Not known	Hong Kong	Cheek	Not known
5	30-F	California	Hand	Diabetes mellitus, chronic vaginal candidiasis, surgery preceded infection
6	30-M	Maryland	Upper extremity and thigh	Diabetes mellitus, renal transplant
7	19-F	Missouri	Face	Not known
8	18-F	Virginia	Hand	Ganglionectomy preceded infection
9	43-M	Mississippi	Hand	Ganglionectomy preceded infection
10	58-M	Vietnam	Olecranon bursa	Non-penetrating trauma to elbow
11	Adult	Canal Zone	Olecranon bursa	Not known
12	42-M	North Carolina	Olecranon bursa	Automobile accident
13	65-M	North Carolina	Olecranon bursa	Automobile accident
14	62-M	Florida	Olecranon bursa	Non-penetrating injury to elbow
15	63-M	Florida	Olecranon bursa	Not known
16	Adult-M	Washington, D.C.	Olecranon bursa	Not known
17	Adult-F	Virginia	Olecranon bursa	Not known
18	29-M	New Zealand	Peritoneal cavity, nose, forehead	Deficiency in cell mediated immunity

Etiologic agent: *P. zopfii* for case no. 1, *Prototheca sp*. for 9, 14, 15, 16 and 17 and *P. wickerhamii* for all others.

Adopted from: Kaplan, W. Protothecosis and Infections Caused by Morphologically Similar Green Algae. Proceedings of 4th International Congress on Mycoses, PHO Pub. 356, 1977. pp. 218-232.

versity of Cincinnati
dical Center

Institute of
Environmental Health

Kettering Laboratory

3223 Eden Avenue
Cincinnati, Ohio 45267
Phone 513 872-5700

APPENDIX J

INQUIRY LETTER MAILED TO LAST KNOWN ADDRESS OF MORTALITY STUDY COHORT MEMBERS WITH UNKNOWN VITAL STATUS

Dear Sir:

The University of Cincinnati, Institute of Environmental Health, is conducting a study at the Metropolitan Sanitary District of Greater Chicago with their full cooperation. Since you were an employee at M.S.D. in the 1960's your answers to the following questions would be of great assistance to us:

(1) Did you work for the M.S.D. in the 1960's? ______________________
Yes or No

(2) If the answer to (1) is Yes, how many years? ______________________

(3) In what year did you leave or retire? ______________________

(4) If the person to whom this letter was addressed is no longer living, please write below the approximate date of death (year and, if possible, month) and the State in which the person was living at that time.

____
Month Year State

Sincerely,

Rita Bradford, R.N.
Research Worker

Enclosure

Patient Care • Education • Research • Community Service

APPENDIX K

Calculating the Expected Number of Deaths in a Proportionate Mortality Study for a Particular Disease

$$\text{Expected Number Deaths for class } m = \sum_{i=1}^{R} \sum_{j=1}^{S} \sum_{k=1}^{A} \sum_{l=1}^{Y} O_{ijklm} D_{ijkl} / T_{ijkl}$$

where i is the subscript for the race groups

j is the subscript for the sex groups

k is the subscript for the age groups

l is the subscript for the year groups

m is the subscript for the m^th^ class (plant, job, etc.) groups

R is the number of race groups

S is the number of sex groups

A is the number of age groups

Y is thenumber of year groups

O is the observed number of deaths among the workers being studied

D is the total number of deaths of the disease for the reference population

T is the total number of deaths for all diseases for the reference population

APPENDIX L

II CLASSIFICATION OF ORGANIZATIONS

0/000/

The word "organization" is meant to include all departments and their sub-units, such as divisions, sections, units, etc.

CODE NUMBER	ORGANIZATION
010	BOARD OF COMMISSIONERS
012	Legislative Section
013	Treasury Section
014	Administrative Section
050	GENERAL ADMINISTRATION
051	Executive Section
052	Affirmative Action Section
060	Management Control Office
061	Administrative Section
070	Management Services Division
071	Administrative Section
072	Management Control Section
073	Safety Section
074	Library Section
075	Communication Services Section
080	Data Processing Division
081	Administrative Section
082	Data Processing Section
083	Systems Development Section
100	RESEARCH & DEVELOPMENT
110	Administration Division
111	Administrative Section
120	Research Division
121	Research Administrative Section
122	Wastewater Treatment Research Section
123	Land Reclamation & Soil Science Section
124	Biology Research Section
125	Aerosol Suppression Study Unit
150	Technical Services and Studies Division
151	Technical Services & Studies Administrativ
152	Methodology Section
153	Radiology Section
154	Experimental Design & Statistical Evaluati
155	Instrument Analyses Section
160	Quality Control Division
161	Quality Control Administrative Section
162	General Quality Control Section
163	WSW - Shift Laboratory Section
164	Industrial Waste Laboratory Section
165	Lemont Laboratory Section
166	North Area Quality Control Section
167	Calumet Quality Control Section
190	Industrial Waste Division
191	Industrial Waste Administrative Section
192	Enforcement Section
193	Field Surveillance & Studies Section
194	Surcharge & Technical Studies Section
195	Industrial Cost Recovery Section

CODE NUMBER			ORGANIZATION
200			PURCHASING
	210		Administration Division
	220		Purchasing Division
	230		Stores Division
		231	Administrative Unit
		232	West-Southwest Storeroom Unit
		233	Calumet Storeroom Unit
		234	North Side Storeroom Unit
		235	Egan Storeroom Unit
	240		Inventory Control Division
250			PERSONNEL
		251	Civil Service Board Section
		252	Executive Office Section
		253	Administrative Section
		254	Examination Section
		255	Training Section
		256	Classification & Compensation Section
		257	Labor & Employee Relations Section
		259	Security Section
300			LAW (also used for attorneys where no original code found)
	310		Executive Division
		311	Executive Office
		312	Clerical Section
	320		Real Estate & General Administration Division
		321	Administrative Section
		322	General Administration Section
		323	Real Estate Section
	330		General Litigation Division
		331	Administrative Section
		332	Litigation Section
	340		Legislative, Finance & Claims Division
		341	Administrative Section
		342	Legislative & Finance Section
		343	Claims & Investigation Section
400			FINANCE (also used for any other Finance Office function not specified below)
	410		Administration Division
	420		General Services Division
	440		Accounting & Auditing Division
		441	Administrative Section
		442	General Accounting Section
		443	Payroll & Labor Distribution Section
		444	Accounts Payable Section
		445	Internal Auditing Section
500			ENGINEERING
	501		Executive Office
	510		Administration Division
		511	Administrative Section
		512	Administrative Services Section
			Administrative Unit
			Cost & Records Unit
			Personnel & Financial Services Unit
			Engineering Vault & Supplies Unit
			Microfilm & Data Processing Unit

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CODE NUMBER	ORGANIZATION
	ENGINEERING (cont'd.)
514	Project Control Section
	Administrative Unit
	Engineering Unit
	Quality Control Unit
	Contract Payment Unit
	Project Cost & Scheduling Unit
515	Field Services Section
	Administrative Unit
	Right of Way Unit
	Survey & Mapping Unit
	Engineering & Review Unit
520	Grants Division
521	Administrative Section
522	Grants Processing Section
523	Grants Application Section
530	Collection Facilities Division
531	Administrative Section
532	Planning Section
533	Sewer Design Section
534	Flood Control Section
535	Local Sewer Section
	Administration Unit
	General Services Unit
	Permit Processing Unit
	General Enforcement Unit
	Field Administration Unit
	North Side Construction Inspection Unit
	West Side Construction Inspection Unit
	South Side Construction Inspection Unit
	Field Enforcement Unit
536	Environmental Design Section
537	Tunnel & Reservoir Section
540	Process Facilities Division
541	Administrative Section
542	Process Planning: Calumet & West-Southwest Se
543	Process Planning: Northwest & North Side Sect
544	Process Design Section
545	Mechanical Design Section
546	Electrical Design Section
547	Structural-Architectural Design Section
550	Construction Division
551	Administrative Section
552	Project Management Section
553	Collection Facilities Section
554	Process Facilities Section
555	Soil Mechanics Section

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CODE NUMBER	ORGANIZATION
600-900	MAINTENANCE & OPERATIONS
600	General Division (also used for unspecified M & O organizations)
601	Executive Office
610	General Division Executive Office
620	Administrative Section
621	Administrative Unit
622	Personnel Allocation Unit
623	Process Control Unit
624	Contract Administration Unit
670	Waterways Control Section
671	Administrative Unit
672	Chicago River Controlling Works Unit
673	Lockport Powerhouse Unit
674	Electrical Maintenance Unit
675	Boat Operations Unit
676	Small Streams Unit
677	Channels Operations Unit
678	Reports, Studies & Data Compilation Unit
680	Technical Projects Section
681	Administrative Unit
682	Nu-Earth Unit
700	North Side Area
710	North Side Executive Office
720	Plant Engineering and Maintenance Section
721	Administrative Unit
722	Mechanical Engineering Unit
723	Electrical Engineering Unit
724	Maintenance Unit
730	Plant Operations Branch
731	Administrative Unit
732	Treatment Operations Section
733	Operations Staff Section
734	Mechanical Operations Section
735	Electrical Operations Section
740	General Plant Services Section
742	Sewer Maintenance Unit
745	Administrative and Time Office Unit
750	Small Facilities Section
751	Administrative Unit
752	Hanover Water Reclamation Plant Unit
780	O'Hare Water Reclamation Plant Section
781	Administrative Unit
783	Operations Unit
784	Maintenance Unit
790	John E. Egan Water Reclamation Plant Section
791	Administrative Unit
793	Operations Unit
794	Maintenance Unit
800	Calumet Area
810	Calumet Executive Office
820	Plant Engineering & Maintenance Section
822	Mechanical Engineering Unit
823	Electrical Engineering Unit
824	Maintenance Unit

CODE NUMBER	ORGANIZATION
830	Plant Operations Branch
831	Administrative Unit
832	Treatment Operations Section
833	Operations Staff Section
834	Mechanical Operations Section
835	Electrical Operations Section
836	Sludge Disposal
840	General Plant Services Section
842	Sewer Maintenance Unit
845	Administrative and Time Office Unit
850	Small Facilities Section
851	Administrative Unit
852	Lemont Sewage Treatment Unit
853	Special Projects Unit
900	West-Southwest Area
910	West-Southwest Executive Office
920	Plant Engineering and Maintenance Branch
921	Administrative Unit
922	Mechanical Engineering Section
923	Electrical Engineering Section
924	Maintenance Section
925	Lubrication Section
930	Plant Operations Branch
931	Administrative Unit
932	Treatment Operations Section
933	Operations Staff Section
934	Mechanical Operations Section
936	Sludge Disposal
940	General Plant Services Section
941	Administrative Unit
942	Sewer Maintenance Unit
943	Building and Grounds Unit
944	Railroad and Labor Pool Unit
945	Administrative & Time Office Unit
946	Harlem Avenue Solids Management Area Unit
947	Lawndale Solids Management Area Unit
990	Land Reclamation Branch
991	Administrative Unit
992	Operations Section

APPENDIX M

DEFINITION OF JOB LOCATION CATEGORIES IN TERMS OF MSD ORGANIZATIONAL CODE (See Appendix L)

West-Southwest Plant: 9XX (except 946, 947, 99X) + 163 + 164 + 232

Calumet Plant: 8XX (except 852) + 167 + 233

Northside Plant: 7XX (except 752, 78X and 79X) + 166 + 234

Downtown: 0XX (except 073) + 2XX (except 232, 233, 234, 235, 259) 3XX + 4XX + 50X + 51X + 52X + 53X (except 535) + 541 + 551 + 60X + 61X + 62X

Variable and Other: (including indeterminant) 073 + 1XX (except 163, 164, 166, 167) + 235 + 259 + 535 + 54X (except 541) + 55X (except 551) + 600 + 67X + 68X + 752 + 78X + 79X + 852 + 946 +947 +99X

APPENDIX N

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

ALPHABETICAL LIST OF CLASSES

1978

CLASS CODE	PAY SCHEDULE	PAY GRADE	CLASS TITLE
1172	PM	1	Accountant
1145	PM	1	Accounts Payable Supervisor
3570	PM	15	Administrative Engineer
1323	PM	11	Affirmative Action Officer
5933	LT	10	Architectural Ironworker
5935	LT	11	Architectural Ironworker Leadman
3120	PM	3	Assistant Architect
3128	PM	3	Assistant Architect-Planner
2243	PM	5	Assistant Attorney (ALSO OTHER ATTORNEYS)
3285	PM	19	Assistant Chief Engineer
6855	PM	6	Assistant Chief Operating Engineer
3221	PM	3	Assistant Civil Engineer (ALSO CIVIL ENG. II)
1791	PM	15	Assistant Director of Personnel
3800	PM	19	Assistant Director of Research and Development
3451	PM	3	Assistant Electrical Engineer
6641	PM	11	Assistant Engineer of Treatment Plant Operations I*
6642	PM	13	Assistant Engineer of Treatment Plant Operations II
3001	PM	1	Assistant Land Use Planner
8350	PM	8	Assistant Master Mechanic
3751	PM	3	Assistant Mechanical Engineer (ALSO MECHANICAL DESIGNER)
1151	GS	14	Assistant Paymaster
1715	PM	1	Assistant Personnel Analyst
1885	PM	15	Assistant Purchasing Agent
2263	PM	3	Assistant Real Estate Administrator
3812	PM	3	Assistant Sanitary Engineer
2479	PM	6	Assistant Security Guard Supervisor
3731	PM	1	Assistant Statistician
3951	PM	3	Assistant Structural Engineer
1176	PM	14	Assistant Treasurer
1344	PM	6	Assistant to Commissioner
3582	PM	5	Associate Agricultural Engineer
3121	PM	5	Associate Architect
3222	PM	5	Associate Civil Engineer (ALSO CIVIL ENG. III)
3452	PM	5	Associate Electrical Engineer
3010	PM	3	Associate Environmental Planner
3002	PM	3	Associate Land Use Planner
3752	PM	5	Associate Mechanical Engineer (ALSO MECH. ENG. II)
1716	PM	5	Associate Personnel Analyst
3813	PM	5	Associate Sanitary Engineer
3732	PM	5	Associate Statistician
3952	PM	5	Associate Structural Engineer**
8668	PM	7	Automotive Fleet Supervisor

*(ALSO JR. PLANT ENGINEER)
**(ALSO STRUC. ENG. AND STRUC. DESIGNER)

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

ALPHABETICAL LIST OF CLASSES

1978

CLASS CODE	PAY SCHEDULE	PAY GRADE	CLASS TITLE
1675	GS	6	Bindery Operator
3604	PM	1	Biologist I
3605	PM	5	Biologist II
3606	PM	9	Biologist III
3725	PM	9	Biostatistician
7543	LT	11	Blacksmith
7541	LT	10	Blacksmith Helper
5351	LT	4	Boiler Setter-Laborer
1113	GS	7	Bookkeeper
1116	GS	13	Bookkeeping Terminal Operator
5353	LT	9	Bricklayer
5359	LT	11	Bricklayer Foreman
8610	LT	1	Bridge Tender
5369	LT	4	Building Laborer
1371	PM	6	Building Services Coordinator
1821	PM	2	Buyer I
1822	PM	6	Buyer II
7323	LT	10	Cable Splicer
8620	GS	3	Cafeteria Helper
1315	GS	12	Cafeteria Supervisor
5153	LT	9	Carpenter
5159	LT	12	Carpenter Foreman
5155	LT	10	Carpenter Leadman
1133	GS	11	Cashier
1842	GS	13	Cataloging and Inventory Analyst
1843	GS	19	Cataloging and Inventory Supervisor
5383	LT	9	Cement Finisher
1459	PM	4	Chief Clerk
6251	LT	9	Chief Electrical Operator
2435	PM	4	Chief Investigator
6859	PM	8	Chief Operating Engineer I (STATIONARY ENGINEER I & II,
6860	PM	12	Chief Operating Engineer II RESPECTIVELY)
6275	LT	12	Chief Power House Dispatcher I
6276	LT	13	Chief Power House Dispatcher II
(3201)			(CIVIL ENGINEER II)
2460	PM	9	Claims and Investigations Administrator
(1445)			(CLERK (VARIOUS))
1321	PM	5	Compliance Officer
1660	GS	5	Composer Typist I
1661	GS	8	Composer Typist II
1190	PM	18	Comptroller
1521	GS	10	Computer Operator I
1522	GS	12	Computer Operator II
(3220)			(CIVIL ENG., VARIOUS, INCLUDING HYDRAULIC AND ENG. OF WATERWAYS CONTROL)

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

ALPHABETICAL LIST OF CLASSES

1978

CLASS CODE	PAY SCHEDULE	PAY GRADE	CLASS TITLE
1524	PM	7	Computer Operations Supervisor
3531	GS	16	Construction Activities Liaison Officer I
3532	GS	19	Construction Activities Liaison Officer II
3275	PM	8	Construction Administrator
3271	PM	11	Contract Administrator
1121	GS	13	Cost Analyst I
6430	LT	3	Crane Oiler
1535	GS	13	Data Coordinator
1663	GS	5	Data Entry Operator I
1664	GS	7	Data Entry Operator II
1670	GS	6	Data Processing Control Clerk
1559	PM	16	Data Processing Manager
3590	PM	21	Deputy Chief Engineer
1175	PM	14	Deputy Comptroller
6210	LT	5	Dynamo Tender
3361	GS	9	Electrical Draftsman I (ALSO ELEC. DES.)
3362	GS	12	Electrical Draftsman II
3363	PM	5	Electrical Draftsman III*
7423	LT	10	Electrical Instrument and Testing Mechanic**
7425	LT	12	Electrical Instrument and Testing Mechanic Foreman***
7424	LT	12	Electrical Instrument and Testing Mechanic Leadman
7343	LT	9	Electrical Mechanic
7347	LT	13	Electrical Mechanic Foreman (ALSO ELEC. FOREMAN)
7349	LT	11	Electrical Mechanic Sub-Foreman
6232	LT	6	Electrical Operator I (ALSO ELEC. OPER. (UNNUMBERED))
§6233	LT	7	Electrical Operator II
3513	GS	13	Engineering Archivist I
3514	PM	4	Engineering Archivist II
3341	GS	9	Engineering Draftsman I
3342	GS	12	Engineering Draftsman II
3343	PM	5	Engineering Draftsman III
3573	GS	6	Engineering Technician I
3574	GS	8	Engineering Technician II (ALSO ENG. ASS'T I & ENG. ASS'T)
3575	GS	10	Engineering Technician III
3576	GS	14	Engineering Technician IV
3577	GS	17	Engineering Technician V
6651	PM	17	Engineer of Treatment Plant Operations I
3512	GS	5	Engineer/Scientist Trainee
3510	GS	6	Environmental Engineer Intern
3511	GS	16	Environmental Graduate Engineer Intern
3600	GS	6	Environmental Scientist Intern
1525	PM	1	Equipment Coordinator
(3641)			(ENG. ASSISTANT I = WATER SAMPLER)

*(ALSO SENIOR ELEC. DESIGNER)

**(ELEC. LINEMAN, ELECTRICIAN AND ELECT. TESTING MECHANIC)

***(ALSO FOR ELEC. LINEMAN FOREMAN)

§--(7423 - ELECTRICIAN)

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

ALPHABETICAL LIST OF CLASSES

1978

CLASS CODE	PAY SCHEDULE	PAY GRADE	CLASS TITLE
1445	GS	7	Field Clerk
3580	GS	17	Field Operations Technician
6810	LT	4	Fireman-Oiler
3722	PM	9	Geologist
3548	PM	5	Graphic Artist
(2473)			(GUARD)
2249	PM	19	Head Assistant Attorney
1825	PM	10	Head Buyer
1457	GS	11	Head Clerk
1859	PM	4	Head Storekeeper
6453	LT	11	Hoisting Engineer
6459	LT	12	Hoisting Engineer Foreman
(3220)			(HYDRAULIC ENGINEER)
3676	PM	9	Instrumentation Chemist III
3677	PM	11	Instrumentation Chemist IV
1875	PM	12	Inventory Control Supervisor
2433	GS	11	Investigator
5989	LT	13	Ironworker Foreman
(6641)			(JR. PLANT ENGINEER)
(3651)			(JR. SANITARY CHEMIST)
3621	GS	5	Laboratory Assistant
3631	GS	9	Laboratory Technician I (AND LAB. TECH. UNNUMBERED)
3632	GS	11	Laboratory Technician II
3633	GS	13	Laboratory Technician III
§8331	LT	4	Laborer Foreman
3290	PM	17	Land Reclamation Engineer
2264	PM	8	Land Use Planner
2223	GS	9	Law Clerk
2229	PM	4	Legal Services Assistant
1953	GS	9	Legal Stenographer
(7425)			(LINEMAN FOREMAN)
7573	LT	10	Machinist
7579	LT	13	Machinist Foreman
7575	LT	11	Machinist Leadman
1680	GS	4	Mail Clerk
8651	LT	3	Maintenance Laborer, Class A
8650	LT	3	Maintenance Laborer, Class A (Shift)
8652	LT	2	Maintenance Laborer, Class B*
1351	PM	5	Management Analyst II
1352	PM	9	Management Analyst III
1353	PM	11	Management Analyst IV
1395	PM	19	Management Control Officer
1349	GS	6	Management Intern

*(+ LABORER (RANK UNSPECIFIED); ALSO = MAINTENANCE)
§--(8652 - LABORER)

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

ALPHABETICAL LIST OF CLASSES

1978

CLASS CODE	PAY SCHEDULE	PAY GRADE	CLASS TITLE
8361	PM	12	Master Mechanic I
8362	PM	14	Master Mechanic II
1871	PM	9	Materials Manager
(3751)			(MECHANICAL DESIGNER)
3381	GS	9	Mechanical Draftsman I
3382	GS	12	Mechanical Draftsman II
3383	PM	5	Mechanical Draftsman III
(3752)			(MECHANICAL ENGINEER II)
3612	PM	1	Microbiologist I
3613	PM	5	Microbiologist II
3614	PM	9	Microbiologist III
3615	PM	11	Microbiologist IV
8660	GS	7	Motor Vehicle Dispatcher
6471	LT	0	Motor Vehicle Driver
1653	GS	7	Multilith Operator I
1655	GS	11	Multilith Operator II
1375	PM	7	Officer Services Supervisor II
6831	LT	7	Operating Engineer I (ALSO OPER. ENGR.)
6832	LT	8	Operating Engineer II
5553	LT	6	Painter
5559	LT	8	Painter Foreman
5555	LT	7	Painter Leadman
1153	PM	7	Paymaster
1712	GS	10	Personnel Assistant
1725	PM	2	Personnel Services Assistant
1651	GS	9	Photocopy Machine Operator
3542	GS	9	Photographer I
3543	GS	13	Photographer II
7743	LT	11	Pipecoverer
7745	LT	12	Pipecoverer Leadman
7773	LT	11	Pipefitter
7779	LT	13	Pipefitter Foreman
7775	LT	12	Pipefitter Leadman
5753	LT	10	Plumber
5759	LT	13	Plumber Foreman
5755	LT	12	Plumber Leadman
2621	GS	14	Pollution Control Officer I
2622	PM	4	Pollution Control Officer II
2623	PM	8	Pollution Control Officer III
2624	PM	10	Pollution Control Officer IV
2625	PM	12	Pollution Control Officer V
2630	PM	5	Pollution Control Projects Coordinator
6272	LT	10	Power House Dispatcher
7393	LT	10	Power House Mechanic

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

ALPHABETICAL LIST OF CLASSES

1978

CLASS CODE	PAY SCHEDULE	PAY GRADE	CLASS TITLE
1306	PM	10	Principal Administrative Analyst
3584	PM	11	Principal Agricultural Engineer
3123	PM	11	Principal Architect
3131	PM	11	Principal Architect-Planner
2247	PM	15	Principal Assistant Attorney
3224	PM	11	Principal Civil Engineer
1455	GS	7	Principal Clerk
1957	GS	9	Principal Clerk Stenographer
1936	GS	7	Principal Clerk Typist
3454	PM	11	Principal Electrical Engineer
3754	PM	11	Principal Mechanical Engineer
1719	PM	11	Principal Personnel Analyst
3815	PM	11	Principal Sanitary Engineer
3678	PM	11	Principal Soil and Rock Mechanics Engineer
1857	LT	4	Principal Storekeeper
3954	PM	11	Principal Structural Engineer
3670	PM	11	Radiation Chemist
2265	PM	14	Real Estate Administrator
1934	GS	4	Receptionist
(3620)			(RESEARCH TECH.)
3663	PM	5	Research Chemist I
3664	PM	9	Research Chemist II
3665	PM	11	Research Chemist III
3666	PM	15	Research Chemist IV
2532	GS	14	Right of Way Negotiator I
2533	PM	5	Right of Way Negotiator II
2523	GS	17	Safety Coordinator
2527	PM	12	Safety Director
2521	GS	13	Safety Inspector
3651	PM	1	Sanitary Chemist I (ALSO JR. SANITARY CHEMIST)
3652	PM	5	Sanitary Chemist II
3653	PM	9	Sanitary Chemist III
3654	PM	11	Sanitary Chemist IV
3655	PM	15	Sanitary Chemist V
9008	GS	14	Scientific Technician
1973	GS	11	Secretary
2473	LT	2	Security Guard (= GUARD)
2475	PM	2	Security Guard Sergeant
2480	PM	10	Security Guard Supervisor
1173	PM	5	Senior Accountant
3583	PM	9	Senior Agricultural Engineer
3122	PM	9	Senior Architect
3130	PM	9	Senior Architect-Planner

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

ALPHABETICAL LIST OF CLASSES

1978

CLASS CODE	PAY SCHEDULE	PAY GRADE	CLASS TITLE
2245	PM	11	Senior Assistant Attorney
1115	GS	11	Senior Bookkeeper
3223	PM	9	Senior Civil Engineer (ALSO CIV. ENG. IV)
1453	GS	3	Senior Clerk
1955	GS	6	Senior Clerk Stenographer
1935	GS	4	Senior Clerk Typist
3453	PM	9	Senior Electrical Engineer
(3363)			(SENIOR ELECTRICAL DESIGNER)
3011	PM	7	Senior Environmental Planner
3003	PM	7	Senior Land Use Planner
3753	PM	9	Senior Mechanical Engineer
1717	PM	9	Senior Personnel Analyst
1380	PM	5	Senior Programmer Analyst
2524	PM	6	Senior Safety Coordinator
3814	PM	9	Senior Sanitary Engineer
3953	PM	9	Senior Structural Engineer
3642	GS	10	Senior Water Sampler
5953	LT	10	Sheet Metal Worker
5955	LT	12	Sheet Metal Worker Leadman
3660	PM	5	Soil Scientist I
3661	PM	9	Soil Scientist II
3662	PM	11	Soil Scientist III
(6859 or 6860)			(STATIONARY ENGINEER)
1938	GS	11	Statistical Typist
1833	LT	2	Stock Handler
1853	LT	3	Storekeeper
1870	PM	9	Stores Supervisor
5973	LT	11	Structural Ironworker
5975	LT	12	Structural Ironworker Leadman
1174	PM	9	Supervising Accountant
3124	PM	15	Supervising Architect
3132	PM	15	Supervising Architect-Planner
3225	PM	15	Supervising Civil Engineer
3455	PM	15	Supervising Electrical Engineer
6290	PM	11	Supervising Electrical Operating Engineer
3755	PM	15	Supervising Mechanical Engineer
1718	PM	12	Supervising Personnel Analyst
3816	PM	15	Supervising Sanitary Engineer
3679	PM	15	Supervising Soil and Rock Mechanics Engineer
3955	PM	15	Supervising Structural Engineer
1752	PM	9	Supervisor of Operating Personnel
6282	PM	8	Supervisor of Turbine Maintenance
6271	LT	12	System Dispatcher
1390	PM	7	Systems Analyst
1392	PM	13	Systems and Programming Supervisor

THE METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO

ALPHABETICAL LIST OF CLASSES

1978

CLASS CODE	PAY SCHEDULE	PAY GRADE	CLASS TITLE
1345	PM	4	Technical Librarian
6620	GS	5	Technician Trainee
1625	GS	4	Telephone Operator
1365	PM	7	Tours and Information Coordinator
3320	GS	6	Tracer
6621	GS	13	Treatment Plant Operator I
6622	GS	15	Treatment Plant Operator II
6623	PM	6	Treatment Plant Operator III
6473	LT	5	Truck Driver
6479	LT	6	Truck Driver Foreman
8681	LT	4	Turbine Laborer
7399	LT	5	Utility Man
3617	PM	3	Virologist I
3618	PM	7	Virologist II
1867	GS	15	Warehousing Specialist
3641	GS	8	Water Sampler (ALSO ENGR. ASSISTANT I)

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APPENDIX O

DEFINITION OF JOB CLASSIFICATION CATEGORIES IN TERMS OF "METROPOLITAN SANITARY DISTRICT OF GREATER CHICAGO ALPHABETICAL LIST OF CLASSES - 1978" (See Appendix N)

Maintenance Laborer A:	8650 + 8651
Maintenance Laborer B:	8652
Fireman-Oiler:	6810
Operating Personnel:	2473 thru 2527, 6210 thru 6282, 6430, 6471 thru 6623, 8331, 8610, 8660, 8668, 8681
Engineer's et al.:	2264, 262X, 2630, 3XXX, 6290, 645X, 664X, 6651, 6831 thru 6860, 9008
Tradesmen:	5XXX, 7XXX, 8350, 836X
Other:	1XXX, 22XX (except 2264), 2433, 2435, 2460, 253X, 8620

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APPENDIX P

DEFINITION OF ORGANIZATIONAL FUNCTION CATEGORIES IN TERMS OF MSD ORGANIZATIONAL CODES (See Appendix L)

Research and Development:	1XX (except 110, 111, 121, 151, 161, 191)
Engineering:	5XX (except 501, 510, 511, 512, 521, 531, 541, 551) + 720 + 722 + 723 + 820 + 822 + 823 + 920 + 922 + 923
Maintenance, Security and Safety:	674 + 724 + 740 742 + 784 + 794 + 824 + 840 + 842 + 924 + 925 + 940 + 942 + 943 + 944 + 073 + 259
Operations:	600 + 670 + 672 + 673 + 675 + 676 + 677 + 678 + 682 + 700 + 730 + 732 + 733 + 734 + 735 + 750 + 752 + 780 + 783 + 790 + 793 + 800 + 830 + 832 + 833 + 834 + 835 + 836 + 850 + 852 + 853 + 900 + 930 + 932 + 933 + 934 + 936 + 946 + 947 + 990 + 992
Administrative: (included Purchasing, Personnel, Law and Finance)	0XX (except 073) + 111 + 121 + 151 + 161 + 191 + 2XX (except 259) + 3XX + 4XX + 501 + 510 + 511 + 512 + 521 + 531 + 541 + 551 + 601 + 62X + 671 + 681 + 710 + 721 + 731 + 745 + 751 + 781 + 791 + 810 + 831 + 845 + 851 + 910 + 921 + 931 + 941 + 945 + 991

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9-1/8"
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5/8"
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